RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXXI.

Published by order of the Government of India.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY,
27, CHOWRINGHEE ROAD.
LONDON: MESSRS. KEGAN PAUL, TRENCH, TRÜBNER & CO.
BERLIN: MESSRS. FRIEDLANDER UND SOHN.

1904.

CALCUTTA
GOVERNMENT OF INDIA CENTRAL PRINTING OFFICE,
8, HASTINGS STREET.

CONTENTS.

PART 1.

PART 2.

PART 3.

LIST OF PLATES, VOLUME XXXI.

PREFATORY NOTICE.

THE *Records of the Geological Survey of India*, established in 1868, were published in yearly volumes until 1897 when, as an experimental measure, they were amalgamated with the *Memoirs*. It has been found, however, that, during the course of systematic survey operations, observations are made of considerable public interest (sometimes in their bearing on current scientific problems and sometimes of economic value) which it would be inadvisable to retain unpublished for the long periods sometimes necessary to complete the work of which such isolated observations form a part. That such observations, with the provisional inferences they permit, are of direct interest and value to the public is shown by the stimulus they give to private workers, whose additional researches and criticisms are often of great value in the preparation of the more complete papers issued afterwards as memoirs dealing with well-defined areas or geological subjects.

Since 1897 this object of publishing accounts of the progress of geological work in India has been partially met by the issue of short memoirs, and by notices in the General Reports published annually by the Director of the Geological Survey. Several reports have, however, been made which are unsuitable for the memoirs, and which are referred to with undesirable brevity in the General Reports; for the publication of these it has been decided to revive the practice of issuing the *Records* as fast as suitable material accumulates. Of subjects of this nature, the analyses and determinations made in the laboratory are amongst those of interest to the public. Several of these, which have been made during the last five years, and not already published, are given with the first part now issued, and in future parts a similar selection from the laboratory results will be made when they appear to be of general interest.

Although every endeavour will be made to keep to the old system of issuing one volume of four parts each year, it is considered inadvisable to adhere rigidly to a rule which might in some cases force the premature issue of results of a palpably imperfect nature, and at other times delay the publication of facts of urgent importance. It has, therefore, been decided to issue the parts as fast as suitable papers are obtained, and it is hoped that this will encourage the contribution of notes made by private workers, who have not at present any other medium of publication in India devoted to purely geological questions. The health of geological research, like all scientific work that aims at the truth, responds to the tonic of honest criticism, and as long as such criticisms show the genetic relationship to original observations which should characterise all scientific research, the *Records* will be open to private workers in India as much as to members of the special department of Government organised to extend our knowledge of the geology and mineral resources of the country.

In order to make the *Records* a complete index of progress since their establishment in 1868, it is intended to take an early opportunity of recording a list of the papers dealing with Indian geology which have been published since the last volume appeared in 1897, and of summarising in separate reviews the progress of geological work and of mineral production for the past five years.

T. H. HOLLAND, *Director,*
Geological Survey of India.

CALCUTTA;
1st January, 1904.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part I.] 1904. [January.

ON A DEPOSIT OF COPPER ORE NEAR KOMAI, DARJILING DISTRICT, *by* H. H. HAYDEN, B.A., B.E., F.G.S., *Deputy Superintendent, Geological Survey of India.*

The above locality is situated near the south-eastern boundary of the Darjiling district, and at about four miles north of the Sam Sing Tea Estate (Jalpaiguri district). It is probably the only known cupriferous locality in this area which had not already been visited either by Mr. Mallet[1] or by Mr. Bose.[2]

The country-rock consists of soft, grey and green slate, belonging to the Daling series. It is greatly crushed and contorted, but the general strike of the beds is N.-E. to S.-W. and N.-N.-E. to S.-S.-W. The dip is variable, but is usually at a high angle to the north-west.

Small bodies of copper ore occur at various places in the slates and in quartzite bands associated with them: these usually amount to little more than small aggregations of copper pyrites, extending for only a few inches in any direction, but at one point situated on the left side of the Mo Chu (Murti river) and about 400 feet above the bed of the stream, a considerably larger body of ore occurs. This consists of fairly large masses of chalcopyrite with some quartz, disseminated more or less in bands through the slates and running apparently parallel to the bedding planes of the rock. The copper-bearing band has been to some extent opened up by Messrs. Chaplain and Thompson, of Sam Sing, to whom I am much indebted for the assistance rendered me by them on my visit to the locality.

[1] Mem. Geol. Surv. Ind., vol. XI; Rec. Geol. Surv. Ind., vol. XV, pp. 56—58.
[2] Rec. Geol. Surv. Ind., vol. XXIII, pt. 4.

A small prospecting shaft has been sunk vertically through the cupriferous band to a depth of about 20 feet, and from this two short drives have been run along the ore body. The total amount of ore-body exposed is only of small extent; it has a thickness varying from about two to four feet, and is composed, as already stated, of soft slate with lumps of copper pyrites and some quartz. The lumps of ore vary in size from masses of about a quarter of a cubic foot in extent to thin ribbons and small grains, but pieces the size of the fist are fairly common.

Assay value of samples.

As only a small amount of development has been done, it was impossible to take a series of samples of the copper-bearing band, but a sample was taken across the working face: this sample represents the total width of ore-body, as it is being extracted and before hand-picking; when assayed, it yielded 3½ per cent. of copper and 1 dwt. 8 grs. of gold per ton, with only traces of silver and zinc.

Further assays were then made of the hand-picked material, this latter consisting of chalcopyrite with a small amount of slate adhering to the ore. These yielded 26 per cent. of copper and 26 per cent. of iron, with a small quantity of gold (too small to weigh). This last result was somewhat surprising, for it was expected that the hand-picked ore would show a considerably higher percentage of gold, on account of the result of the assay of the unpicked ore. The discrepancy is no doubt due to the fact that the amount of material available for sampling was so small that it was impossible to obtain fair average samples, and until a considerably larger amount of the ore-body has been opened up, it will be impossible to form any accurate estimate as to the average value of the band; this, as well as the true nature and extent of the ore-body, can only be ascertained by more extensive development and prospecting. It must, however, be remembered that the fact that the assays of a few isolated samples have yielded favourable results cannot be looked upon as a guarantee that the average value of the whole ore-body is equally high, and that in common with most forms of metalliferous mining, the undertaking must be at present of a distinctly speculative character.

Nature of the ore body.

With regard to the nature of the ore-body, it has already been stated by Mallet[1] that in all the localities in which copper has been found in the Darjiling district and in the Western Duars, "the ore occurs disseminated

[1] Mem. Geol. Surv. Ind., vol. XI, p. 72.

through the slates themselves, and not in true lodes," and, so far as I was able to ascertain, this statement applies equally to the cupriferous band at Komai. The deposit is, in fact, of the kind classed by Professor Henry Louis [1] under the term "Disseminations through sedimentary beds," and which he regards as a "connecting link between the two great classes of deposits, the symphytic"—or those deposited contemporaneously with the sedimentary beds—"and the epactic"—or those which have been introduced subsequently. Deposits of this class he regards as having been formed by means of mineralising solutions which have penetrated the sedimentary beds subsequently to their consolidation and elevation. As an example of this class of ore deposit Professor Louis cites, amongst others, the well-known *Kupferschiefer* of Mansfeld: it is probable that the Komai band is of a very similar character, though in the latter bed the individual particles of ore are very much larger than those found in the *Kupferschiefer*. So far as it was possible to follow the band underground, it appears to run in a direction parallel to the bedding planes of the slates, the dip and strike of both being the same. How far this may continue to be the case, it is impossible to say, for the slates are greatly contorted, both dip and strike varying considerably, and faults are common, though apparently of no great throw.

Extent of the band.

The copper-bearing band had at the time of my visit been followed to a depth of not more than 30 feet below the surface and for a horizontal distance of not more than 40 feet. No outcrops were visible on the surface, and the presence of jungle and soil-cap render it impossible to trace the band. It is only therefore by careful prospecting that its extent can be ascertained. For this purpose it would be necessary to make cross-cuts at certain points along what appears to be the line of strike of the band. Should it be found to be continuous, cross-cut adits could be driven with each into the hill to meet the band, and it could then be mined in the usual manner.

Facilities for mining.

The country-rock being a fairly soft slate, mining should be comparatively inexpensive, though timber would probably be necessary in places. The present workings being situated at a height of several hundred feet above the river, there is no likelihood of difficulties arising from the presence of water.

[1] Phillips and Louis, "A treatise on Ore Deposits," 2nd Edn., 1896.

There is an abundant supply of water and timber, and the locality is fairly accessible, being situated at about twelve miles from the nearest railway station (Chalsa, Bengal Duars Railway); only the last four miles would be through hilly country, through which a road could be made at no great cost, while the remaining distance is practically level and roads already exist.

The general conclusions may therefore be summed up as follows:—

Summary.

The copper ore occurs in the form of chalcopyrite disseminated through slate, the cupriferous band having a thickness—so far as it has been at present opened up—of from 2 to 4 feet.

A sample taken from the working face in the prospecting drive yielded on assay 3½ per cent. of copper and 1 dwt. 8 grs. of gold per ton of ore. The material being extracted when the sample was taken, was said to be poorer than most of that which had been previously obtained.

A sample of hand-picked ore yielded on assay 26 per cent. of copper and 26 per cent. of iron with some gold. Silver and zinc are practically absent.

The copper-bearing band has been followed only for a distance of less than 40 feet; should it be found to be continuous and equal in value to that portion already exploited, it might possibly be mined profitably, owing to the fact that other conditions are favourable. But the value of the band cannot be ascertained without further prospecting and development, its extent being at present quite unknown.

NOTE ON THE ZEWAN BEDS IN THE VIHI DISTRICT, KASHMIR, *by* R. D. OLDHAM, *Superintendent, Geological Survey of India.*

Between the peaks of Wastarwan, below Avantipur, and Zebanwan, above Srinagar, the hills recede from the river Jhelum, leaving a broad bay of alluvium, which constitutes the district of Vihi. Near the river the hills are composed of ancient and altered volcanic rocks — the "Panjal traps" of Lydekker, but those at the head of the valley are composed of limestone and associated sandstones and shales of his "Zanskar" system. At the contact between these two series of rocks is a band of more shaly beds, in which, and in the associated and overlying limestones, there are numerous fossils indicating a permian age. These rocks have been noticed and recorded by Dr. Verchère, Colonel Godwin-Austen, and Mr. Lydekker, and as I do not propose to write a fresh detailed description, the following notes will be confined to an enumeration of all the localities where they are to be found—some too small to be marked satisfactorily on the only available map—and to recording any facts of importance which appear to have escaped notice or record by earlier observers.

For the nomenclature of the beds dealt with I have adopted Dr Verchère's name of "Zewan beds," as having the priority; the fossils they contain show that they are of permian age, but the term would be too wide for descriptive application, even if there were no other objections to that course, nor do I consider it desirable to follow Mr. Lydekker in using the word "Kuling," until it has been shown that the time limits connoted by that term are at least approximately the same as those of the Zewan beds.

The limits adopted for this stage are necessarily vague at present. Below it comes the great series of volcanic rocks, above it a great series of limestones, some sandstones and subsidiary shales; between these two there is a band, of variable thickness, of sandy and shaly beds with subsidiary, though massive, limestones, which are abundantly fossiliferous in the Vihi district.

In the following description I shall take the localities where these beds are exposed in serial order, commencing with that nearest the river on the west side, and working round the edge of the valley from it.

1. *The Zewan exposure.*—About three quarters of a mile from the village of Panduchak, and between it and the village of Zowur, both of which are marked on the Atlas of India map, lies the village of Zewan, and near it, on a spur from the Zebanwan mountain, is the small exposure of fossiliferous rocks described by Verchère and Godwin-Austen and figured by both; it forms fig. 5 of the latter's paper in *Quart. Journ. Geol. Soc.*, vol. XXII.

The beds of this exposure dip to S.-S.-E. and S.-E., and are cut off on the east by a fault running nearly parallel to the dip. The other boundary runs along the bedding, and seems to be an original contact, whether conformable or not it is impossible to say with certainty, nor can it be positively asserted that the contact is an original one and not faulted, for the bottom bed is composed of 10 to 12 feet of white quartz which might well be a vein.

Above this quartz, between it and the fossiliferous limestones and shales, come sandstones and shale, the former containing pebbles and strings of conglomerate. Below the principal band of pebbles, and corresponding to No. 2 of Godwin-Austen's section, is a band of black shale, full of small shiny specks, apparently carbonised plant remains. This rock weathers nearly white and resembles the matrix in which *Gangamopteris* occurs at the locality next to be mentioned; at Zewan I found no remains of that plant or any other recognizable fossils in this rock.

The uppermost beds of the section consist of an alternation of shales and limestones, in which are abundant remains of bryozoa, and brachiopods: among the former *Fenestella*, *Protoretepora* and *Acanthocladia* are common, the latter comprise species of *Lyttonia*, *Productus*, *Spirifera* and allied genera, besides others undetermined.

2. *The Risin spur, near Khunmu.*—The next locality to be mentioned is close to the village of Khunmu, on the spur known as Risin, and is that which forms Godwin-Austen's fig. 4. It does not seem to have been noticed by Verchère, or its mention was omitted on account of its small size and the absence of marine fossils: this exposure, whose length does not much exceed 300 feet measured along the strike, is that in which Dr. Noetling found *Gangamopteris* associated with fishes and reptilian remains.[1] The plants occur in two distinct beds, the uppermost of which is the highest bed in the section, the overlying beds being covered up by the fan of the ravine to the

[1] General Report for 1902-03, p. 22.

south. As a consequence it is not possible to determine with certainty the relation of these plant-bearing beds to those, containing marine fossils, which are found in the exposures on either side.

There is no reasonable doubt that these beds belong to the same series as the Zewan beds, for the occurrence of *Gangamopteris* is evidence of a permian age, that which may safely be ascribed to the Zewan beds on the strength of the fossils they contain; but it must be mentioned that in spite of the general parallelism of dips between the fossiliferous beds and the volcanics on all the sections, and the consequent suggestion of an identity in the relations between the two sets of beds, yet there is no sign on the Risin exposure of that conspicuous band of white quartz which forms the contact bed both at Zewan and on the exposure next to be described.

3. *The Guril ravine.*—About one quarter to half a mile from the Risin spur is the boundary of the main exposure of the Zewan stage and overlying rocks. This runs down the ravine called Guril, near Khunmu, and strikes the alluvial area about half a mile from the Risin outcrops. The section in this ravine forms Godwin-Austen's fig. 9, but here, as in other sections, the actual thicknesses and individual beds mentioned only apply to the precise line along which the section was measured. a very short distance on either side both thickness and beds will be found to differ, a difference partly due to original thinning out of the beds, and partly to the effects of the disturbance they have undergone.

4. *Mandakpal.*—On the opposite side of the Vihi valley the main boundary runs down to the alluvium at the village of Mandakpal; the section here forms Godwin-Austen's fig. 10. Lydekker mentions this as a locality where fossils are especially abundant, but such is not my experience; either he hit on a spot, missed by me, where they were specially abundant, or he did not strike the fossil locality in the Guril ravine, where I found fossils in greater abundance and better preservation than at any other place.

Neither at Mandakpal nor the next two localities to be mentioned did I see the white quartz bottom bed which is so conspicuous in the western exposures; it appears to be represented by a chert bed.

5. On the spur south of Mandakpal a tongue of limestone caps the ridge: in it are the Buddhist quarries mentioned by Verchère.

6. The spur which runs down to Rechpura village is also capped by a tongue of limestone containing Zewan brachiopods. In neither of these two exposures is the limestone underlaid by shaly beds.

7. Further south is the section described by both Verchère and Godwin-Austen, and forming the latter's fig. 2.

8. Finally, there is the small exposure near Barus on the river Jhelum, forming Godwin-Austen's fig. 7, which, like the Zewan exposure, is bounded on one side by a fault; at Barus the boundary fault runs nearly north and south, and forms the eastern boundary.[1]

In all these exposures there is an appearance of conformity between the Zewan beds and the underlying volcanic rocks, and previous observers have assumed, where they have not asserted, a conformity between the two series. Dr. Verchère asserts it positively and quotes the occurrence of limestone beds interbedded with the volcanics. I have seen some of these, but cannot regard them as proof of conformity, since they are by no means of the type of those in the Zewan stage, while there are no fossils in them.

Against the hypothesis of conformity two considerations may be urged; firstly the great variation in development of the shaly bottom beds of the Zewan stage, and secondly the abrupt cessation of the volcanic rocks on every section. The variation in the sections is remarkable, from the pebbly sandstones of Zewan, which indicate littoral if not terrestrial conditions on the one hand, to the immediate contact of limestone with the volcanics at Rechpura, and the same variation in the nature of the bottom beds of the fossiliferous series was seen on other sections outside the Vihi district. This variation certainly suggests an unconformity, though an explanation, consistent with conformity, has been given by Mr. Lydekker, that the volcanic eruptions continued longer in some localities than in others, thereby obliterating, in one place, the lower beds of the Zewan stage which were being formed in another, where volcanic activity had ceased; though possible, this explanation is rendered doubtful by the fact that on those sections where the volcanic rocks are largely developed, they continue in full force up to the boundary between the two series, and then cease absolutely, no case of interbedding of volcanic rock with the sedimentary deposits of the Zewan stage having been seen by me. For this reason I am inclined to differ from my predecessors and to regard the relation of the Zewan beds to the underlying volcanic series as one of unconformity, though this unconformity need not involve a great time-interval.

[1] Some villages mentioned above are not marked on the Atlas of India; they will be found on the map attached to Dr. Verchère's paper in Journ. As. Soc. Beng., 1866.

REPORT ON THE COAL DEPOSITS OF ISA KHEL, MIANWALI, PUNJAB, *by* R. R. SIMPSON, B.Sc., *Coal-mining Specialist, Geological Survey of India* (with Plates 1 and 2).

CONTENTS.

I.

POSITION AND PHYSICAL FEATURES OF THE COALFIELD.

Position. The area examined is between 32°51′—33° 4′ and 71° 12′—71° 37′, and is situated in the Isa Khel tehsil of the Mianwali district, Punjab.

Physical features. The whole of the coal deposits are found in the rocks of the Punjab Salt Range, which, pierced by the river Indus at Kálabágh has a westerly trend for 24 miles as far as Malla Khel, and from thence pursues a southerly course back towards the river.

The Indus at Kálabágh is 700 feet above sea-level, and from it the Isa Khel plain rises gently through an average height of 350 feet to the foot of the mountains, the highest summits of which exceed 4,000 feet in height. The character of the plain is that of a sandy desert, the grains of rock becoming coarser as the mountains are approached.

The foot of the range is occupied by fan-like boulder deposits which from their ruggedness are extremely difficult to traverse

The mountains rise steeply from the plains and are deeply scored by ravines, some of which, as at the Chicháli and Baróchi passes, cut right through the heart of the range, and form lofty precipices.

Except for an occasional stunted shrub or tuft of coarse grass vegetation is completely absent from the mountain slopes. The rain-fall is extremely small, but is sufficient to support a scanty vegetation on the lower ground (about one year in four, according to Thorburn). Drinking water is scarce and bad, being strongly impregnated with soda salts. Upon the inhabitants of the scattered villages in the neighbourhood it appears, however, to have little ill effect, so that it is evidently possible to become accustomed to its use.

The only villages of importance are Kálabágh (32° 58′—71° 37′) on the north, and Isa Khel (32° 41′—71° 21′) on the south, both on the western bank of the Indus. There are no main roads, transport being effected by means of camels, donkeys, or oxen.

The nearest railway connection is at Mári (32° 28′—71° 39′), about 1 mile from Kálabágh, and on the eastern bank of the Indus, from whence a short branch line runs to a junction at Daud Khel (32° 42′ —71° 37′) with the Kundián-Campbellpur branch of the North-Western Railway.

II.

PREVIOUS OBSERVERS.

Since the earlier half of last century a number of observers[1] have from time to time recorded notes on the geology of the Trans-Indus Salt Range.

Attention was first directed to the possible economic value of the coal beds in 1864, when Dr. Oldham[2] was deputed by Government to examine the coal deposits of the Salt Range. Among other localities he visited the area to be treated of in this communication. In his report he records the fact that coal occurs of both mesozoic and tertiary age, he describes the coal localities of Kálabágh, Kotki, Chushmea (Chásmiah), and Malla Khel, and, with the exception of the Kálabágh deposits, from which he estimated that some 45,000 maunds might be extracted, condemns them as permanent sources of fuel. In 1879-80, Mr. A. B. Wynne[3] thoroughly examined the Trans-Indus extension of the Salt Range, and mapped a considerable area in detail. In his memoir he mentions a number of coal localities in Isa Khel, but considers that "the layers themselves are of little value as sources of fuel."

The general geological details given in this report are largely founded upon the results of Mr. Wynne's field work.

III.

THE ORIGIN OF THE PRESENT ENQUIRY.

Early in 1902 Mr. R. W. Hodges, Engineer-in-Chief, Khushalgarh-Thal Railway, tried in his locomotives coal obtained from Malla Khel,

[1] Dr. Andrew Fleming, Journ. As. Soc. Beng., vol. XVII, pt. 2, p. 516; vol. XVIII, pt. 2, p. 688; vol. XXII, pp. 274, 345, 444. Dr. A. L. Verchère, *ibid*, vol. XXXIV, pt. 2, p. 42.

[2] Dr. Oldham, "The Coal Resources and Production of India," 1864, p. 14.

[3] Mr. A. B. Wynne, Mem. Geol. Surv. Ind., vol. XVII.

Chasma (probably Chásmiah), and Kotki. He reported that the coal gave results almost as good as Bengal coal costing from R26 to R35, and better results than those obtained from Dandót coal at R19 per ton. As a consequence of this report an enquiry into the economic value of the deposits was called for from the Director of the Geological Survey of India.

Late in January 1903 I arrived in the Mianwali district and spent some five or six weeks in an examination of the Isa Khel coal deposits and a consideration of their economic value. The results of this enquiry and the conclúsions drawn from them are given in this Report.

IV.

GEOLOGY OF THE AREA.

Structural features.

As is commonly the case in folded mountainous regions, there is an intimate coincidence between the physical features and the geological structure of the ground. The axial line of the hill range which partially encircles the Isa Khel plain is also the axis of an anticline steeply scarped on that side of it presented to the plain. The development of this escarpment is principally due to denuding agencies, but it has been considered that assistance has been rendered by parallel fracturing in the vicinity of the base of the range. Another prominent feature is the extremely disordered, slipped, faulted, and displaced arrangement of the talus or undercliff portion of the escarpment. The cause of this confusion may be traced to the fact that the more tender, and in the north, saline rocks being reached by percolating water, have yielded to the wasting influences, and caused the harder masses above to become dislodged.

Generalised section.

In the following table is given a general section of the rocks as seen in the numerous ravines which intersect the range :—

Formation.	Description.	Thickness in feet.
Post-tertiary . .	Limestone boulder-conglomerate.	500.
Pliocene and miocene	Clays and soft, grey sandstones.	about 10,000.
Eocene . . .	Nummulitic limestones and marls.	0—1,500.

Formation.	Description.	Thickness in feet.
Cretaceous (?) . .	Strong, light-coloured sandstones, with coal-seams near the top.	0—450
Jurassic . . .	Hard, white limestones with dark sandstone and shale bands at the top.	130—600.
	Variegated sandstones and shales, with thin coaly layers and alum shales.	300—500.
Trias . . .	Grey shales with thin limestones.	350—450.
Carboniferous . .	Grey limestones with calcareous sandstones.	400—1,000.
Saline series . .	Grey shales with dolomitic bands, salt marl, gypsum, and salt rock.	350?

As may be seen from the accompanying maps (plates I and II)[1] and the sections (figs. 1 and 2) shown below, there is considerable variation in the thickness and extent of the beds. The chronological order, however, remains the same, the disparity between sections from different localities being due to denudation, faulting, and surface slipping.

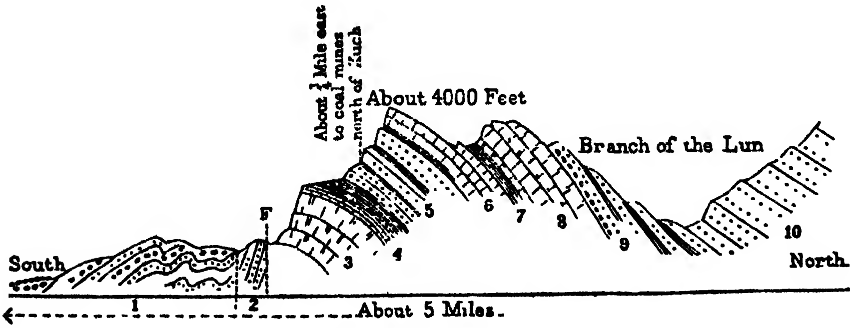


FIG. 1.—*Sketch section north of Kálabágh.*

1, Upper siwalik. 2, Lower siwalik (?). 3, Carboniferous. 4, Trias. 5, Variegated jura with irregular coal seams. 6, Marine jura. 7, Lower eocene. 8, Nummulitic. 9, Lower tertiary sandstone. 10, Lower and middle siwalik. F, Fault.

[1] Partial reproductions from Mr. Wynne's memoir, Geol. Surv. Ind, vol. XVII.

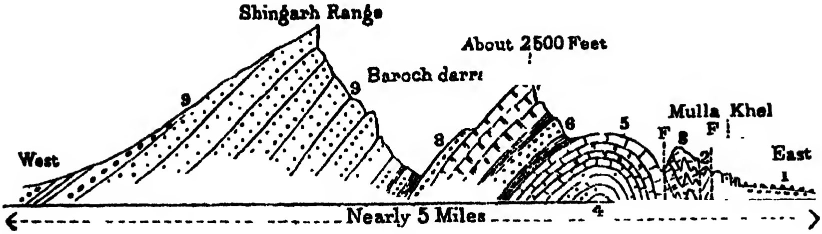


FIG. 2.—*Sketch section of the Hills near Mulla Khel.*

1, Boulder zone. 2, Crushed tertiary sandstone and limestone. 3, Eocene limestone. 4, Variegated sandstone with coaly bands. Jurassic. 5, Limestone. Jurassic. 6, Sandstone containing a seam of coal near the top. Cretaceous (?). 7, Eocene limestone. 8, Upper nummulitic, representative conglomerate. 9, Siwalik group. F, Fault.

Age of the coal beds.

Coal is found belonging to two different geological formations. The older coal is found on several horizons towards the base of the jurassic system, amongst a group of soft, variegated sandstones and shales, having a maximum thickness of about 500 feet. It occurs in thin lenticles, sparingly distributed throughout sandy shales, which are frequently pyritous (alum shales). In only two localities (near Kálabágh and Kuch), have these coals a thickness at all workable. The younger coal is found from 50 to 100 feet below the base of the nummulitic limestone, in soft, yellow-tinted sandstone of a maximum thickness of 450 feet. This sandstone bed, on somewhat slight palæontological evidence, has been considered to be of cretaceous (neocomian) age, but Mr. Wynne, in his memoir, prefers to refer to it as the "supra-jurassic sandstone." The coal occurs on at least two horizons, and is variable in both quality and thickness. In the Maidán Range, in the neighbourhood of Malla Khel, the principal seam is found to improve in quality and to have a thickness varying from a few inches up to more than 5 feet. It can be traced, with local thinnings, and occasional apparent absence, for some five or six miles to the south.

Except for the tilting consequent upon the anticlinal structure of the range, the rocks, in which the coal of both ages occurs, are little disturbed. The maximum dip does not exceed 50°, and is usually considerably less.

V.

ECONOMIC DETAILS OF THE COAL AREAS.

Artificial division of the coal areas.

For the purposes of this report it will be convenient to split up the ground into a number of partly natural and partly artificial areas, each of which will be dealt with separately. These divisions are—

A. Kálabágh.
B. Kuch.
C. The ground between the Chicháli pass and Malla Khel.
D. The Maidán Range.

A.—Kálabágh.

Geological details.

About 2 miles north of Kálabágh, and at a height of 700 feet above the level of the Indus, coal of jurassic age is found in grey and yellow sandstones about 100 feet thick. The dip of the beds is N. 14° E. at an angle of 62°. Coal occurs on three horizons, a rough section across the beds being as follows:—

Grey and yellow shales	Thick.
" " " sandstones and shales . .	10′ 0′
Upper coal-seam	1′ 8″—4′ 0″
Grey and yellow sandstones and shales . . .	50′ 0″
Middle coal-seam	1′ 6′—3′ 0″
Grey and yellow sandstones and shales .	30′ 0″
Lower coal-seam	1′ 3″
Grey and yellow sandstones and shales .	10′ 0″
Yellow sandstones with variegated shales . .	Thick.

The outcrops rise eastwards at an angle of 27° and in a short distance the coal-seams thin out and disappear. On the east they are faulted and are found abutting against white sandstones and purple-brown shales. The total length of the coal outcrops, measuring on the slope, is 750 feet. Within this short distance the seams are remarkably variable, as can be seen from the following sections:—

(1)

Upper seam (from 20 feet below the surface).

		Ft.	In.
Hard, grey shales . . .		...	
Soft, " " . . .	Portion worked.	0	8
Coaly shales	Portion worked.	0	2
Bright COAL . . .	Portion worked.	0	3
COAL with pyrites and shales	Portion worked.	0	3
Good COAL with pyrites .	Portion worked.	1	2
		2	6

(2)

Upper seam (from 40 feet below the surface and 40 feet from (1)).

		Ft.	In.
Hard, grey shales . . .		...	
Good COAL		0	4
Iron pyrites		0	1
COAL		0	5
Coaly shale	Portion worked.	0	1
Grey "		0	6
Coaly "		0	6
Grey "		0	6
Good COAL		0	10
Grey shale . . .		0	1
Good COAL		1	2
COAL shale and pyrites . .		0	5
Good COAL		1	1
		6	0

In another drift 50 feet distant from (2) the section is—

(3)

Upper Seam.

	Ft.	In
Coaly shale	0	5
Grey "	0	3
Coaly "	0	2
Grey "	0	5
COAL, shale and pyrites . . .	0	9
Good COAL with pyrites . . .	1	4
	3	4

The middle seam shows even more pronounced variability. representative section is—

(4)

Middle Seam.

	Ft.	In.
COAL and pyrites	0	6
Shale	0	1
Coaly shale and shale . . .	0	8
COAL, coaly shale and pyrites .	1	9
Shale	0	4
COAL and pyrites	0	6
	3	10

The lower seam has only a small lateral extent (the length of its outcrop is about 100 feet). The coal is bright, strongly pyritous, and has a maximum thickness of 15 inches.

About a quarter of a mile south of these outcrops the rocks bend over to the south, forming a local anticline the axis of which is faulted. A few feet south of the fault a thin band of shales, with scares of woody lignite, is found. At some former time several drives have been made in these beds. An exploration of the tunnels showed that in no place does the lignite exceed 12 inches in thickness.

Quality of the coal.

The coal is a hard, black, shining lignite, with a specific gravity of 1·57. It is non-coking and has a jetty appearance when freshly cut. It displays no regular cleavage, and has a slightly conchoidal fracture. The ratios of the amounts of inorganic matter, volatile matter, and fixed carbon it contains is approximately as 5 : 8 : 11. (For detailed analyses see table on page 25.) It contains a large proportion of sulphur, as iron pyrites, and is liable to spontaneous combustion. It burns with a smoky flame and an unpleasant odour.

The coal has been employed by the engineers of the Public Works Department for brick-burning purposes at Mianwali, but it does not appear to have given satisfaction, for they have reverted to the use of wood.

Quantity of fuel available.

As has been stated above, the coal beds are thin, patchy, and of very limited extent. Estimates of the amount of fuel in such deposits can only be very approximate, as it is impossible to determine to what depth from the outcrop the coal-seam extends. Assuming, however, that it extends to a depth from the surface equal to the length of the outcrop, that the dip of the beds is 63°, and that an average thickness of four feet might be extracted, the total amount of fuel would be—

$$\frac{650 \times 650 \times 4}{23\frac{1}{2}} = 71{,}915 \text{ tons.}^{1}$$

Of this amount $\frac{578 \times 150 \times 1{\cdot}12 \times 4}{23\frac{1}{2}}$ or 16,529 tons[1] would be obtainable from above free drainage level.

[1] These calculations and those given later involve the following factors—

$$\frac{A \times B \times C \times D \times E}{F}$$

Where—

A = Horizontal distance in feet.
B = Vertical " "
C = Workable thickness " "
D = Co-secant of the angle of dip.
E = Fraction workable.
F = Number of cubic feet in one ton of coal = 23½.

Working costs.

The present output from the Kálabágh mines is about 3 tons per day. With systematic working it could probably be increased to 10 tons per day, which for 300 working days would amount to 3,000 tons per annum. With such an output the coal above free drainage level would be exhausted in some 5 or 6 years. Under these circumstances it would not be advisable to incur the expense of European management, or of the erection of more than the minimum of mining plant. The works might be laid out and periodically inspected by a skilled mining engineer. The actual work of supervision would be well within the powers of an intelligent native foreman.

With the present methods of working, the coal on rail at Mári costs, exclusive of the cost of supervision, R4-2-0 per ton. Details. of this cost are as follows:—

	R	a.	p.	
Mining and cleaning the coal . .	1	8	9	per ton.
Transport to Mári	2	9	3	" "
Total cost .	4	2	0	" "

The low cost of mining is due to the fact that, so far, nothing but outcrop scratching has been done. Should regular mining be undertaken, the making and maintenance of underground roads would have to be provided for. Probably the total cost for mining and supervision would not be less than R3-8-0 per ton.

It is likely that with a larger demand the rates for ox transport would appreciate, so that a charge, under this head, of R3 per ton would probably not be too high a figure.

Estimate No. I, Kálabágh colliery, for an output of 3,000 tons per annum.

	Cost per ton.		
	R	a.	p.
Mining and cleaning the coal, with supervision .	3	8	0
Ox transport to Mári	3	0	0
Total cost .	6	8	0

B.—Kuch.

Geological details.

About six miles north of Kálabágh, and some two miles north of the village of Kuch (33° 1′—71° 35′), jurassic coal beds are again seen. The outcrops are found, at a height of 1,500 feet above the Indus, on the face of a steep scarp rising northwards at an angle of 35°. The locality is somewhat difficult of access. The coal-bearing strata are made up of shales, sandy and coaly shales, and coal-seams, the total thickness varying from 20 to 50 feet. The beds strike S. 80° W. and dip at an angle of 42° towards the north and into the face of the mountain. The outcrops rise gently towards the west, the coal beds thinning out and disappearing at either end. The total length of the coal outcrops was estimated to be about 600 feet, actual measurement being debarred by the precipitous nature of the scarp. There are two coal-seams, respectively 16 inches and 12 inches thick, separated by a thickness of 15 feet of slightly carbonaceous shale. Both seams are lenticular in mode of deposit.

At distances of 200 yards, half a mile, and one mile east of these outcrops, small patches of the same coaly shales are found; but in none of them does coal of appreciable thickness occur.

Quality of the coal.

The coal is a hard, black, shining lignite, resembling the Kálabágh coal in appearance. Its specific gravity is 1·47. Its analysis (see table on page 25) shows that it contains considerably less ash than the Kálabágh coal, but double the percentage of moisture (*i.e.*, 10·19%). For this reason its calorific value is lower. It contains only a moderate amount of sulphur (2·35%), and burns with a smoky flame and unpleasant odour.

Quantity of fuel available.

These coal beds present the same features of uncertainty in regard to thickness and persistence as do those in the neighbourhood of Kálabágh. Assuming that the coal-seams extend from the surface to a depth equal to the workable length of their outcrops (500 feet), and that an average thickness of 16 inches might be worked, the total amount of fuel available would be—

$$\frac{500 \times 500 \times 1{\cdot}33}{23{\cdot}5} = 14{,}149 \text{ tons.}$$

As the strike of the beds is approximately parallel to the contour of the scarp, no part of the coal could be obtained with free drainage.

The beds might be unwatered by driving an adit from some point lower down the scarp to strike the coal at a convenient depth. Taking into consideration, however, the small amount of coal obtainable, the high cost of working due to the thinness of the seam, and the difficulty of access from the *nala* beneath, it is not likely that such expense would be justified.

Working costs.

For these reasons, therefore, I am of the opinion that systematic mining of the Kuch coal-seam would not repay the necessary outlay. The details of the present cost of mining coal from the outcrops and placing it on rail at Mári are as follows :—

	R	a.	p.	
Mining and cleaning the coal . .	1	11	6	per ton.
Ox transport to Mári . . .	3	1	6	" "
Total cost .	4	13	0	" "

C.—The ground between the Chichāli pass and Malla Khel.

Geological details.

About one mile east of Kotki (32° 59′—71° 28′), a village situated in the Chichāli pass, the coaly band is again seen, but is not of workable thickness.

Terrka nala, 33°0′—71°24.

Further up the pass and about ¼ mile north of Kotki, a band of pyritous shales with coaly strings, the whole about 30 feet thick, is found a short distance below the nummulitic limestone. In the Terrka nala, about 2 miles north of Kotki, coal again occurs in the sub-nummulitic rocks. Two bands of soft coal, each 3 inches thick, separated by 6 inches of shale were measured. These beds dip at an angle of 60°, and their outcrop cannot be traced for more than a few yards.

The ravines between Chasmiah (32°59′—71°20′) and Malla Khel (32°56′—71°13)′.

In the numerous glens which debouch from the mountains between Chasmiah and Malla Khel the coaly beds of jurassic age are almost invariably to be seen. The lenses of coal, however, never exceed 3 inches in thickness, and are usually thinner.

Quality of the coal.

The lenses of coal in these deposits are dull, black, brittle, woody lignites with a specific gravity of 1·17. Their volatile content is slightly in excess of the fixed carbon. They burn with a dull, smoky flame, and are low in calorific power. They have no economic value.

D.—The Maidán Range.

Geological details.

In the Baróchi ravine, about half a mile west of Malla Khel, the lower jurassic coaly shales are well shown. Further up the ravine the light-coloured sandstones overlying the jurassic rocks are found to have increased to 450 feet in thickness. In the upper part of these beds two coal-seams are found The upper seam, 50 feet below the nummulitic limestone, is only 9 inches thick, and appears to have only a limited lateral extent.

The lower seam occurs about 50 feet below the first, and is about 3 feet thick, and of fairly good quality. Its outcrop crosses the Baróchi stream at a point about 2 miles west of, and 300 feet above, Malla Khel. The dip at this point is to the west at an angle of 45°. Traced northwards from the ravine the seam rapidly thins to 9 inches, and becomes more stony and pyritous. Two miles further north, near Shaikh Nikka summit (3,990 feet), the supra-jurassic sandstone is found crowning the range. The band of coaly shales is present but the coal is frequently absent and never exceeds 8 inches in thickness.

Southward from the Barochi stream-bed the outcrop can be followed for a distance of about 1,500 feet through a height of 800 feet, beyond which point the ground becomes too difficult to be traversed. In this length of outcrop, although the wall of the ravine slopes at an angle of 60°, ten excavations, varying in depth from 4 to 7 feet, were made. The average thickness thus proved was 2 feet 10 inches. About ½ mile further south, skilful cragsmen who climbed the western wall of the ravine were unable to find a trace of the coal seam. The rocks at this point are excellently exposed, so that it must be concluded that the seam has thinned out.

One-third mile still further south, at the Karma waterfall (32°55′—71° 11′), at a height of 650 feet above the plains, the coal is found to vary in thickness from 1 foot to 1 foot 7 inches. Rather more than a mile south of the point where its outcrop crosses the Baróchi seam, the coal-seam is found at a height of 1,000 feet above the plains and about 100 feet below the crest of the scarp. I was unable to examine the outcrop myself, but native miners clambered down, and after excavating to a depth of 3 feet, measured the seam 4 feet in thickness.

In the upper part of the Paronga nala, although diligent search was made for the coal-seam, it was not found. The rocks, however, are somewhat obscured by talus from the limestone, so that it is by no means certain that the seam is absent. On the southern slope of the same nala and about 2 miles south of Malla Khel, the seam is 12 inches thick, of which only two inches is actually coal.

Paronga gorge, 32°55′—71°12′.

Passing south-westward over the spur into the Chasma nala, at a height of 1,150 feet above the plain, the seam is found to have thickened to 3 feet 5 inches, and to dip to the west at an angle of 30°. The outcrop can be traced for about 100 feet and then becomes obscured by talus. Half a mile to the south the crushed and broken fragments of the seam can be seen in the undercliff. Further up the nala and about 1,000 feet above the plain the coal outcrop is found on its usual horizon in the scarp. The thickness at this point is 1 foot 10 inches.

Chasma nala, 32°54′—71°12′.

Two-thirds of a mile to the south, in the Kardi nala, the thickness has increased to 3 feet. In the Makarwál nala the thickness of the coal is 2 feet 6 inches, the rocks dipping N. 70° W. at an angle of 30°. The outcrop, although occasionally obscured by talus, can be traced to the southward for rather more than half a mile.

Kardi and Makarwál nalas, 32°53—71°12′.

In the northern branch of the Kerai gorge the coal is 3 feet 6 inches thick and has a woody character. The dip varies from east at a high angle, on the lower slopes, through horizontal, to west at a low angle, higher up the nala. In the southern gorge the thickness of the seam in one place is reduced to one foot six inches. The outcrop is, however, not well seen.

The Kerai gorges, 32°52′—71°12′.

Half a mile further south, in Lumshiwál gorge, the seam has thickened to 5 or 6 feet, and becomes very shaly in character. South of this ravine the axis of the anticline becomes depressed and the coal-bearing beds are covered up by newer rocks.

Lumshiwál nala, 32°52—71°12′.

The coal is a bright-black, fairly hard lignite, showing little cleavage, but acquiring a woody character towards the south. Exposed to the atmosphere it disintegrates. Its specific gravity varies from 1·24 to 1·38, the average value being 1·31. It burns with a yellow, smoky flame, and has occasionally a coking character. The average analysis of carefully

Quality of the coal.

selected samples from twenty-one different excavations on the outcrop of the seam, is—

	Average of 21 samples of coal from the Maidán Range. Per cent.	Average of 39 samples of coal from the Giridih and Raniganj coal fields. Per cent.
Moisture	9	?
Volatile matter	37	31·3
Fixed carbon	40	53·7
Ash	10	15·0
Sulphur	4	?
	100	100

For purposes of comparison the average analysis of a number of Bengal coals is given in a parallel column.

The evaporative power[1] of the Maidán Range coal, determined by means of Thompson's calorimeter, averages 11·8, a value which compares very favourably with that of Bengal coal, which varies from 10 to 13·4.

Comparing the above analyses, Bengal coal is seen to be superior in regard to fixed carbon, the proportions being nearly as 4 is to 3. Respecting ash the Maidán Range coal has the advantage, the percentages being in the ratio of 2 to 3.

The percentage of sulphur in the Bengal coal analyses is not stated. It probably, however, does not exceed 1% as against 4% for the Maidán Range coal.

The worst feature of Isa Khel coal is the large amount of moisture it contains, a characteristic of all lignites. Moisture in a coal has a doubly pernicious influence, for not only does it decrease the percentages of the carbon and hydro-carbons in the coal, but it also lessens its useful heating value by the amount of heat required to convert it (the moisture) into steam.

It should be remarked that in the experiments for ascertaining the evaporative power of Isa Khel coal, the moisture was previously driven off by heating the fuel for some time at a temperature of 212° F. It was found that the coal would not burn successfully in the calorimeter unless this precaution was adopted.

[1] Pounds of water evaporated at 212° F. by 1 pound of coal.

In the following table the previously published analyses of Isa Khel coal are given:—

Tables of coal analyses.

No.	Locality.	Remarks.	Volatile matter.	Fixed carbon.	Ash.	Coking qualities.
1 *	Chásmiah . .	Best quality, jet black with a resinous fracture and lustre. Sp. gr. 1·25.	50	35	15	Cokes partially.
2 *	" . .		50	40	10	" "
3 *	" . .		25	40	35	" "
4 *	" . .		47	21	32	" "
5 *	Sultan Khel .	Picked specimen .	47	45	8	
6 †	Kotki . .		36	34	30	

In the following tabulated statement details are given of the analyses, in the Geological Survey laboratory, of a number of carefully selected average samples collected by me from small excavations on the coal outcrops. By reference to the maps (Plates I and II), the precise locality from which each sample was collected may be ascertained.

* Dr. A. I. Verchère, Journ. As. Soc Beng., vol. XXXIV, pt. 2, p. 44—47.
† Dr. Andrew Fleming, *ibid.*, vol. XXII, p. 346.

Analyses of coal samples from Isa Khel, Mianwali, Punjab.

Number on map.	Locality.	Depth from surface in feet.	Section of seam.	Remarks.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Evaporative power.[1]	Colour of Ash.	Coking properties.
1	Kálabágh . . .	20	2′ 6″	Bands of coal, shale, and pyrites, 4′ thick, of which 2′ 6″ is coal.	7·43	25·77	36·28	30·52	...	...	Light brown.	*Nil.*
2	" . . .	15	1′ 6″	Bands of coal, shale, and pyrites, 4′ thick, of which 1′ 6″ is coal.	4·04	24·16	42·29	25·12	4·39	11·89	Grey.	"
3	Kuch	7	1′ 4″	......	10·19	22·74	46·12	18·60	2·35	9·63	Brown.	"
4	Chásmiah . . .	0	½″ to 3″	Lenses of coal in shale.	4·52	38·70	36·78	20·00	...	...	"	Cokes.
5	Baróchi gorge .	6	Coal 2′ 1″, coaly shale 10″	Sample from the coal band.	5·20	33·26	36·27	16·00	9·27	12·19	"	Cokes poorly.
6	" " . .	6	2′ 7″	......	3·49	41·87	43·08	11·56	...	...	"	" "
7	" " . .	6′ 6″	3′ 1″	......	10·87	38·77	42·81	5·04	2·51	10·45	Reddish brown.	*Nil.*

[1] Pounds of water evaporated at 212° F. by 1 pound of coal.

Analyses of coal samples from Isa Khel, Mianwali, Punjab—continued.

Number on map.	Locality.	Depth from surface in feet	Section of seam.	Remarks.	Moisture.	Volatile matter	Fixed carbon.	Ash.	Sulphur.	Evaporative power.[1]	Colour of Ash.	Coking properties.
8	Baróchi gorge . .	5	...	...	11·01	41·95	40·84	6·20	...	...	Reddish brown.	*Nil.*
9	" . . .	4	1' 5'	.	9·57	35·[illegible]9	32·23	20·[illegible]0	2·61	9·03	" "	"
10	" " . .	4	2' 0"	...	[illegible]·02	3[illegible]·[illegible]2	30·[illegible]5	18·1[illegible]	..		" "	"
11	" " . .	7	3' 8"	...	[illegible]·26	40·1[illegible]	43·[illegible]8	2·85	2·03	11·89	Dark brown.	"
12	" " (Karma).	1	Coal 0' 10", coaly shale 1' 0".	......	5·02	[illegible]2·4[illegible]	35·16	26·82	...	..	Brown.	"
13	" " . .	1' 0"	Coal 1' 0', coaly shale 1' 0".	Sample from the coal band	8·70	[illegible]·92	41·[illegible]	18·13	...	.	Reddish.	"
14	" " . .	3	4		13·34	39·79	11·50	3·52	2·35	..	"	"
15	Chasma gorge (north)	5	3' 2"	.	1[illegible]·83	41·11	40·14	2·12	.		Dark red.	"
16	" " " .	4	3' 8"	...	5·02	42·40	4[illegible]·34	5·60	5·64	14·35	Gray.	Cokes.

[1] Pounds of water evaporated at 212° F. by 1 pound of coal.

Analyses of coal samples from Isa Khel, Mianwali, Punjab—concluded.

Number on map.	Locality.	Depth from surface in feet.	Section of seam.	Remarks.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Evaporative power.[1]	Colour of Ash.	Coking properties.
17	Chasma gorge (south) .	3	1′ 4″	......	15·70	35·97	37·50	7·88	2·95	...	Brown.	*Nil.*
18	" " " .	5	Coaly shale 1′ 0″, coal 1′ 10″.	......	8·62	35·60	38·03	13·92	3·85	11·07	Reddish.	"
19	" " " .	4′ 4″	1′ 10″	......	5·16	41·66	45·04	8·14	...	...	Gray.	Cokes partially.
20	" " " .		1′ 10″	......	5·64	40·60	43·00	5·58	5·18	13·93	Brown.	Cokes.
21	Kardi gorge . .	5	3	......	8·30	40·56	44·02	2·80	4·26	11·27	"	Cokes partially.
22	" " . . .	3′ 6″	3′ 8″	... ..	11·30	41·64	45·00	2·06	...	...	Reddish.	*Nil.*
23	Makarwál gorge . .	4′ 10″	2′ 11″	......	2·40	43·54	41·38	12·68	...	...	Brown.	Cokes.
24	Kerai gorge (south) .	5′ 4″	4′ 10″	......	8·12	38·86	47·05	3·42	2·55	11·89	Reddish.	*Nil.*
25	" " (north) .	7′ 2″	5′ 6″	.. .	7·52	35·43	43·00	9·72	4·33	11·68	Brown.	"

[1] Pounds of water evaporated at 212° F. by 1 pound of coal.

Quantity of fuel available.

The sub-nummulitic coal-seam of the Maidán Range appears to have attracted little attention previous to my visit. The only mention it has excited is from Mr. Wynne,[1] who records the occurrence in the Baróchi gorge of "a carbonaceous shaly layer, 2 feet or so thick, but irregular." As I have remarked on a previous page, the coal-seam can be traced along the ridge, fairly continuously, between the Baróchi pass and a point due west of Sultan Khel village, a distance of rather more than six and one half miles. The general direction of the outcrop of the seam is parallel to the range, and the dip is westward and into the mountains. Under these circumstances, were it not for the denuding agencies which have carved out the numerous nalas which intersect the range, none of the coal could be worked with free drainage except by driving adits through the underlying rocks. Owing to this denudation, however, the outcrop pursues an undulatory course, in one place being found high up on a spur and in another low down in a nala. Taking advantage of these natural features, levels driven in from the lowest points on the outcrop in the nalas would unwater considerable areas of the seam. Without a detailed survey it is impossible to calculate the extent of these areas and the quantity of coal they contain. An approximate estimate may, however, be made.

Granting that the seam is workable over two-thirds of the length of its outcrop, that its average thickness is 2 feet 3 inches, and that a strip averaging 250 feet in width could be unwatered by means of levels driven in from the lowest points on the outcrop, then the quantity of coal workable with free drainage would be—

$$\frac{5{,}280 \times 4{\cdot}33 \times 250 \times 2{\cdot}33}{27}$$
$$= 493{,}235 \text{ tons.}$$

Owing to the steepness of the scarp on which the coal-seam outcrops, a large area of the deeper coal might be unwatered by driving adits through the underlying rocks to cut the seam in depth. Presuming that the slope of the scarp averages 30°, and that the dip of the seam varies from 30° to 45°, then the length of an adit which would cut the seam 500 feet from its outcrop, would, as can be seen from fig. 3 on page 29, vary from 866 to 965 feet.

Therefore, in this way, by means of adits not exceeding 1,000 feet in length, it would probably be possible to unwater and extract a second 500-foot strip of the coal-seam.

[1] Mem. Geol. Surv. Ind., vol. XVII, p. 264.

With the same premises the amount of coal in such an area would be double the previous estimate, or 986,470 tons.

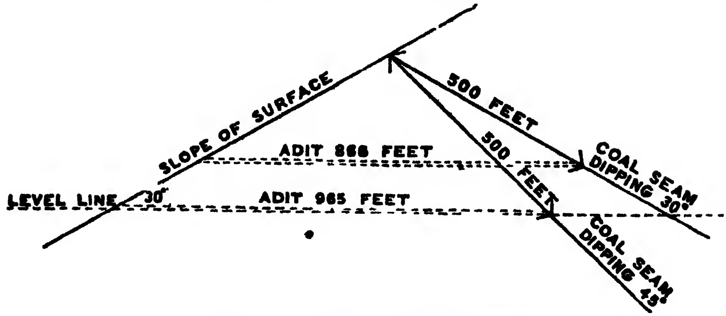


FIG. 3.—*Proposed Adit Levels.*

Coal consumers.

Except for a trifling local demand for brick-burning purposes, the only consumer of the coal would be the North-Western Railway Company. The railway station nearest to the coal deposits is Mári, situated on the east bank of the Indus, opposite to and about one mile from Kálabágh. A short branch line, 6 miles in length, connects Mári, at Daud Khel, with the Kundián-Campbellpur section of the North-Western Railway.

Market value of the coal.

At Mári the average cost of Bengal coal is R22 per ton. Of this rate nearly 89 per cent. is on account of freight charges. The Engineer-in-Chief of the Khushalgarh-Thal Railway, after trials in his locomotives of coal from Malla Khel, Chasma (Chásmiah), and Kutki (Kotki), has stated that the coal gives results almost as good as Bengal coal, and apparently better than Dandót coal. It may be remarked that the coal with which these trials were made was apparently obtained from the lower jurassic beds, and would be distinctly inferior to the sub-nummulitic coal of the Maidán Range. I am not, however, prepared to endorse this flattering estimate of the quality of Isa Khel coal. The high percentage of moisture is a serious defect, whilst the large amount of small coal, which will probably be produced in mining it, will also detract from its value. It is, however, undoubtedly a useful fuel, and its market value, compared with Bengal coal, may perhaps be estimated to be in the ratio of 2 to 3.

Position for a colliery.

Coal winnings might be established in any of the gorges debouching between Malla Khel and Sultan Khel. The most suitable points of attack would, however, probably be in the Baróchi, Makarwál, and Kardi nalas.

Probable output.

The question of output would largely depend on the number of winnings. Fifty tons per day would probably be the maximum output obtainable from a pair of winnings. With a sufficient labour-supply there would probably be little difficulty in maintaining an output of 150 tons per day, or, say, 45,000 tons per annum.

Mining.

Owing to the comparative soundness of the enclosing strata, the mining cost would probably not be excessive. The chief item of expenditure would be on account of mine roads. As the coal above free drainage level becomes exhausted and it becomes necessary to win the coal by means of adits, this expenditure would be enhanced. Taking all circumstances into consideration, I should estimate the mining cost at R5 per ton (1).

Transport.

Ox or camel transport for such a quantity of coal would be out of the question. It would be necessary to construct a light railway to some point on the bank of the Indus from whence the coal might be conveyed in boats to the ferry-boat-landing opposite Mári railway station. The best starting-point for such a line would probably be Kummure[1] (32° 51′—71° 25′), where the saltpetre factories are situated. The total length of the line, with terminal points at the mouths of the Makarwál, Kardi, and Baróchi ravines, would not exceed 16 miles. The nature of the country is easy, being a plain sloping from the mountains to the river. The gradient of the line would thus be in favour of the load. There would be no streams of importance to bridge, but in one or two places works for passing flood water would probably be necessary. An approximate estimate of the cost per mile of a light tramway of 2 feet gauge over such country would be as follows:—

	Cost per mile R
Permanent way	8,000
Formation	2,000
Bridges	2,000
Locomotives	3,500
Rolling stock	3,000
Workshop and stores . . .	1,000
General charges	500
TOTAL .	20,000

[1] I did not visit Kummure.

The total cost for 16 miles of line, therefore, would be R3,20,000. Interest and depreciation charges on this sum at 11 % would amount to R35,200, which. on an output of 45,000 tons per annum, would represent a constant charge on the coal of 12½ annas per ton. Running charges would increase this figure to R1-4 per ton. Owing to the considerable elevation of the mouths of some of the proposed mines, it would not be possible, in all cases, to take the tramway up to the mine entrance.. It would, therefore, be necessary to provide, for short distances, other means for transport. Probably self-acting inclines and, in some cases, even ox transport would be employed. On this account, therefore, it would be prudent to allow 8 annas for this charge. The total charge on account of transport from the mines to Kummure would therefore be, say, R1-12-0 per ton. From Kummure the coal would be carried in boats to the boat landing at Mári, a distance of about 16 miles, and placed on rail there. Probably this could be done at a cost not exceeding 6 annas per ton. Adding this amount to the previous figures, the total cost of transporting the coal from the mines and placing it on rail at Mári is seen to be R2-2-0 per ton (2).

Management.

For the laying out of the workings and the general direction of the mining and mechanical operations it would be prudent and, in the long run, economical to secure the services of a mining engineer with a thorough knowledge of the best mining practice of the day. Such an appointment should ensure a fair trial of the mining possibilities of the neighbourhood, and prevent what usually happens in a new mining district, *i.e.*, the waste of large quantities of valuable mineral through reckless and ill-considered methods of working.

The charges on account of management and office expenses may be estimated to amount to 6 annas per ton (3).

Estimate No. II, Maidán Range colliery, for an output of 45,000 tons per annum.

	Cost per ton. R	a.	p.
Mining (1)	5	0	0
Transport (2)	2	2	0
Management (3) . . .	0	6	0
TOTAL .	7	8	0

D

At a cost of R7-8 per ton Isa Khel coal would undoubtedly be able to displace Bengal or Dandót coal over considerable sections of the North-Western Railway Company's lines.

It should be remembered that the above estimates are for undressed coal only. Should it be found desirable to compress the small coal into briquettes, a coal-briquetting factory might be erected at Mári. The increased cost of production would be more than recouped by the higher selling value of the briquetted fuel.

VI.

LABOUR.

The question of labour-supply will be a difficult one. The coal miners of Kálabágh and Kuch probably do not exceed 30 in number. The population of the locality is scanty, and most of the labour will require to be imported. The neighbourhood is by no means an inviting one. Drinking water is scarce and bad. The coolies whom I employed in the Maidan Range for prospecting purposes, although they were Kálabágh men, suffered from its use. They were paid high wages but could not be induced to remain longer than three weeks. The inhabitants of the surrounding villages, however, appear to suffer no ill-effects from the use of the water, and probably imported coolies, if they could be persuaded to remain long enough, would soon become accustomed to it.

After the construction of the railway, the difficulty might be obviated by conveying water from the Indus, in tanks, to the miners' villages.

VII.

METHODS OF WORKING.

The present method.

The present mode of extracting the coal at Kuch and Kálabágh is extremely crude and unscientific. The workings consist of a series of irregular caverns supported at infrequent intervals by knobs of unworked coal from 2 to 4 feet in diameter. At the time of my visit, the longest drive was only 87 feet in length, and, at the face, would not be more than 40 feet below the surface. Should this method of working be continued, the life of the mine will be of short duration, and the bulk of the available coal will be lost.

Except for its high angle of dip and its inconstancy in thickness, the coal-seam of the Maidán Range will not be a difficult one to mine. The roof and floor of the seam are of sound sandstones and shales, so that roads made in the seam would probably stand well.

The proposed method.

The best mode of working to employ, would, in my opinion, be the "longwall" system with certain modifications. The essential feature of this method is that the whole of the coal is removed in one working, the roads being supported by building "packs" or stone walls on either side of them.

A winning might be modelled on the following lines :—

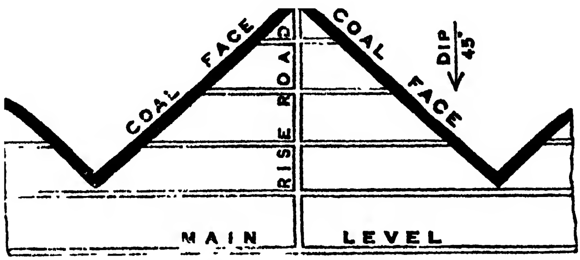


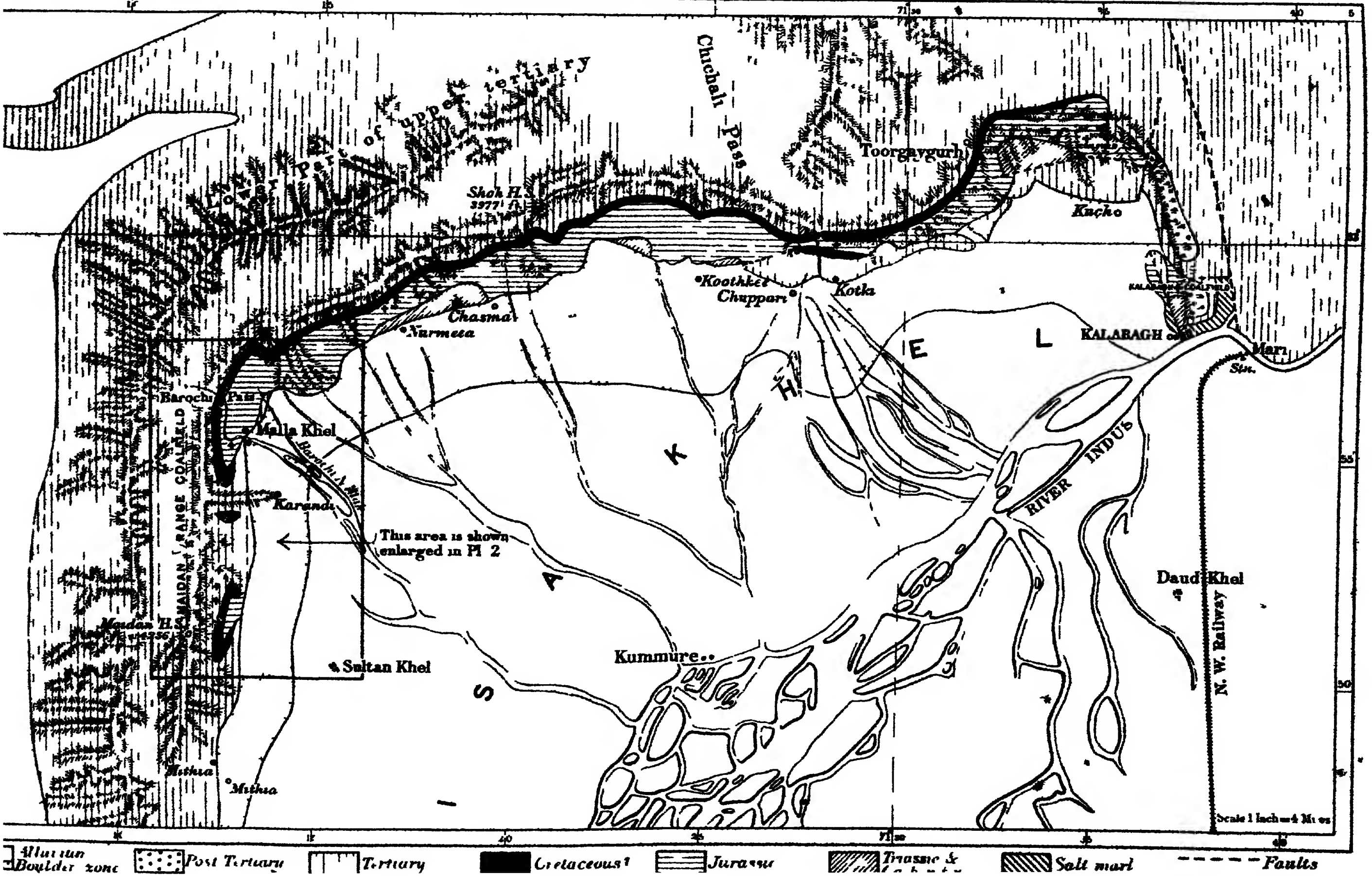
FIG. 4.—*Sketch of proposed method of working.*

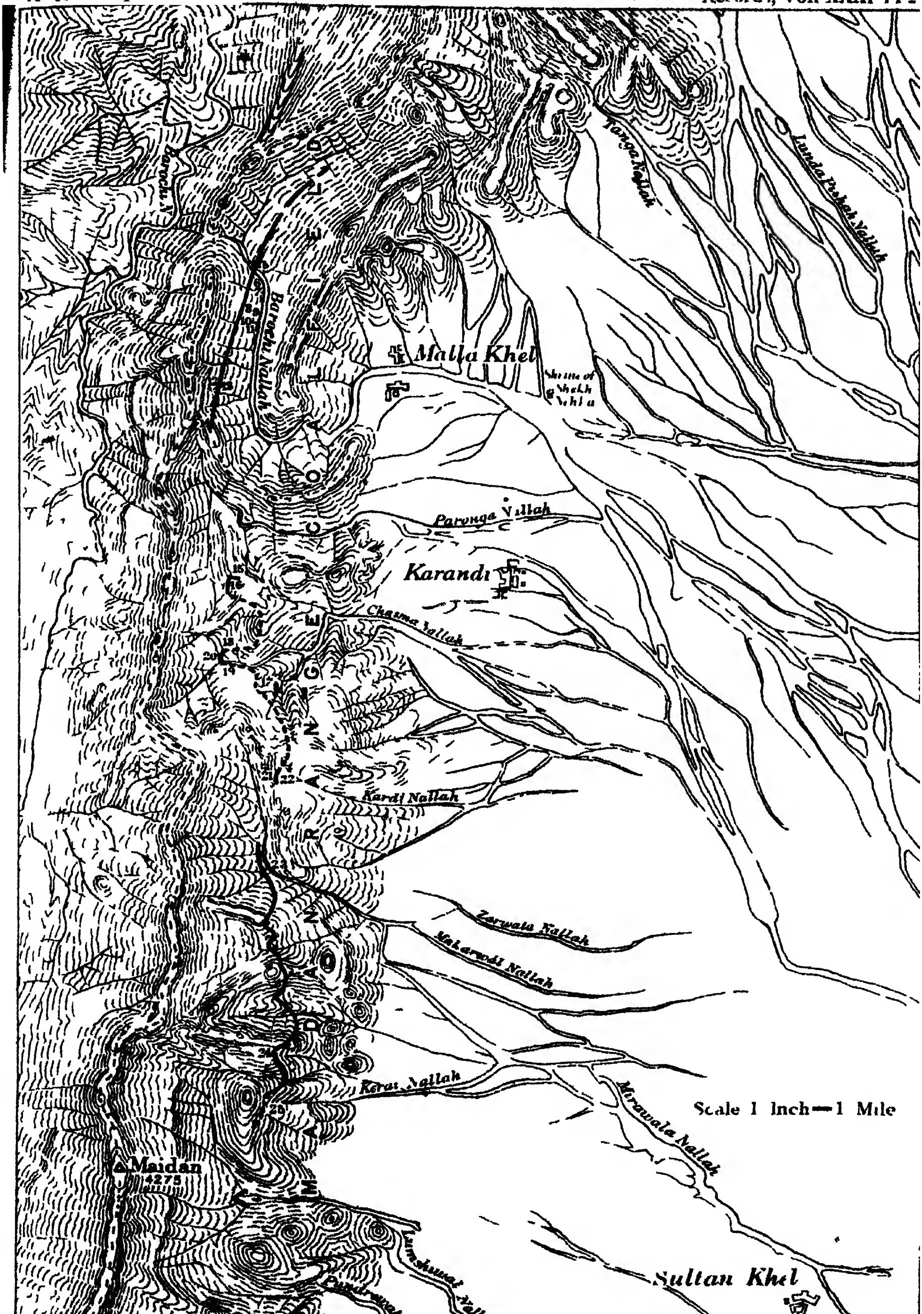
A pair of levels, 60 feet apart, rising 1 in 150, would be driven in from the outcrop and connected at intervals of 100 feet by cross-drives. From these levels, at intervals of 500 feet, rise-roads would be driven up on the full slope of the seam. From these rise-roads, subordinate levels would be turned off to the right and left every 60 feet, and the coal face kept at an angle of about 45 degrees. The coal would be brought along the minor levels to their junctions with the rise-road, lowered to the main level by means of a balance platform with the balance weight running below the tramway, and then run out to the day. The material for building the roadway "packs" would be obtained from the stone blasted down in making the roadway of the requisite height.

The whole of the coal might be extracted except an outcrop barrier of, say, 100 feet in thickness, which would serve to keep back surface water.

Ventilation and lighting.

It will undoubtedly be necessary to ventilate the mine workings artificially. In the mode of working outlined above, the lower main level would form the intake air-road. By placing doors in the cross-roads, the air-current would be forced to travel into the end of the level and would return by means of the upper of the pair of main levels, first, however, being forced to travel round the coal-face by means of doors or curtains placed across the minor levels. A current of fresh air would thus be supplied to the men working at the coal-face, and noxious gases given off by the coal itself would be removed. The air-current would be induced by means of small, quick-running fans, preferably of the Capell or Schiele type. It is quite possible that as the workings become developed, inflammable gases may be met with. Consequently considerable caution should be used in opening out the mines, and regular daily examinations for "gas," with locked safety-lamps, should be made. Should "gas" in any quantity be encountered, it would be necessary to prohibit the use of open lights and to resort to safety-lamps. The ideal lamp for placing in the hands of native miners would be one of the various makes of electric incandescent lamps,—probably the Süssmann lamp would be the most satisfactory. The superiority of this type of lamp lies in the fact that it may be placed in any position without becoming extinguished. From the point of view of an intelligent European miner, the disadvantages are its greater weight compared with an oil safety lamp, and its uselessness in testing for "gas." In the hands of the native the former drawback is trifling and the latter feature a positive advantage of no mean value.


Lower part of upper tertiary
Chichali Pass
Toorgavgurh
Shoh H. 3977 ft
Kacho
Koothkee Chuppari
Kotla
Chasma
Narmeta
Barochi Pass
Malla Khel
Barochi N.
Karandi
MAIDAN RANGE COALFIELD
Maidan H.
This area is shown enlarged in Pl 2
Sultan Khel
Mithia
KALABAGH
Mari
Stn.
ISA KHEL
RIVER INDUS
Kummure
Daud Khel
N. W. Railway
Scale 1 Inch = 4 Miles
Alluvium Boulder zone
Post Tertiary
Tertiary
Cretaceous?
Jurassic
Triassic &
Salt marl
Faults



MAP SHOWING THE OUTCROPS OF SUB-NUMMULITIC COAL NEAR MALLA KHEL TRANS-INDUS SALT RANGE

(The numbers refer to the numbering of the coal samples in the Table of Analyses)

REPORT ON THE UM-RILENG COAL-BEDS, ASSAM, *by* P. N. BOSE, B.SC., F.G.S., *late Deputy Superintendent Geological Survey of India.* (With Plate 3.)

Towards the close of the season 1901-1902, I came upon some more or less rolled fragments of coal in the bed of a stream 4 miles west of Barapani (9 miles from Shillong along the Gauhati cart-road). In the beginning of the last season, 1902-1903, I succeeded in tracing them to their source, and found two indistinct exposures of coal much covered by soil and talus, and, at the time of my visit, by dense grass jungle at the foot of Dinghie Hill, close to the headwaters of the Um-Rileng river, near a small village of the same name. The Chief Commissioner of Assam, on hearing about this new find—the first, I believe, on the northern side of the Khasi and Garo Hills—expressed a desire for its exploration in some detail. A grant of five hundred rupees was promptly sanctioned for excavations, and arrangements were made for their execution through the local Public Works Department under my supervision. I have to express my obligations to Mr. Perram, the Chief Engineer, and Mr. Sweet, the Executive Engineer, for their cordial help throughout the exploration. Sub-Overseer Sukhlal Mitra, who has been in charge of the operations from the commencement, has all along worked with highly commendable energy and enthusiasm.

Coal was exposed in several trenches and pits east of the village of Um-Rileng early in December, but the pits started at a higher level nearer Dinghie Hill went through 21 to 30 feet of sub-recent deposits (clay with pebbles and boulders) without disclosing the coal-bearing rocks. I then thought it necessary to have recourse to borings. But there being no boring tools available in the Province, they had to be ordered from Calcutta, and the borings could not be taken in hand until the middle of May, and then they had to be stopped as the monsoon set in (about the middle of June). This season, they were resumed about the middle of October, but for various reasons (heavy rain being one) there was but little progress until the beginning of November.

The first boring was made at a distance of 1,500 feet from trench marked No. 1 in the accompanying plan [1] where coal was first exposed by digging, in a pit (No. 4) which had been excavated through clay and loam interspersed with boulders to a depth of 22 feet. It was carried down 12 feet below that depth through sandstone and clay which might well be members of the coal-bearing group. At the 34th foot the rod struck what appears to have been the quartzite of the Shillong series. The second boring was put down at a distance of about a mile and a quarter east-south-east from trench No. 1, in a pit (No. 5) which had been dug down to 34 feet through clay and loam in which occur pebbles and boulders of various sizes. The boring has been carried down 26 feet below that depth through clay and soft, coarse sandstone which I am inclined to refer to the group of coal-bearing rocks. But no coal has been struck.

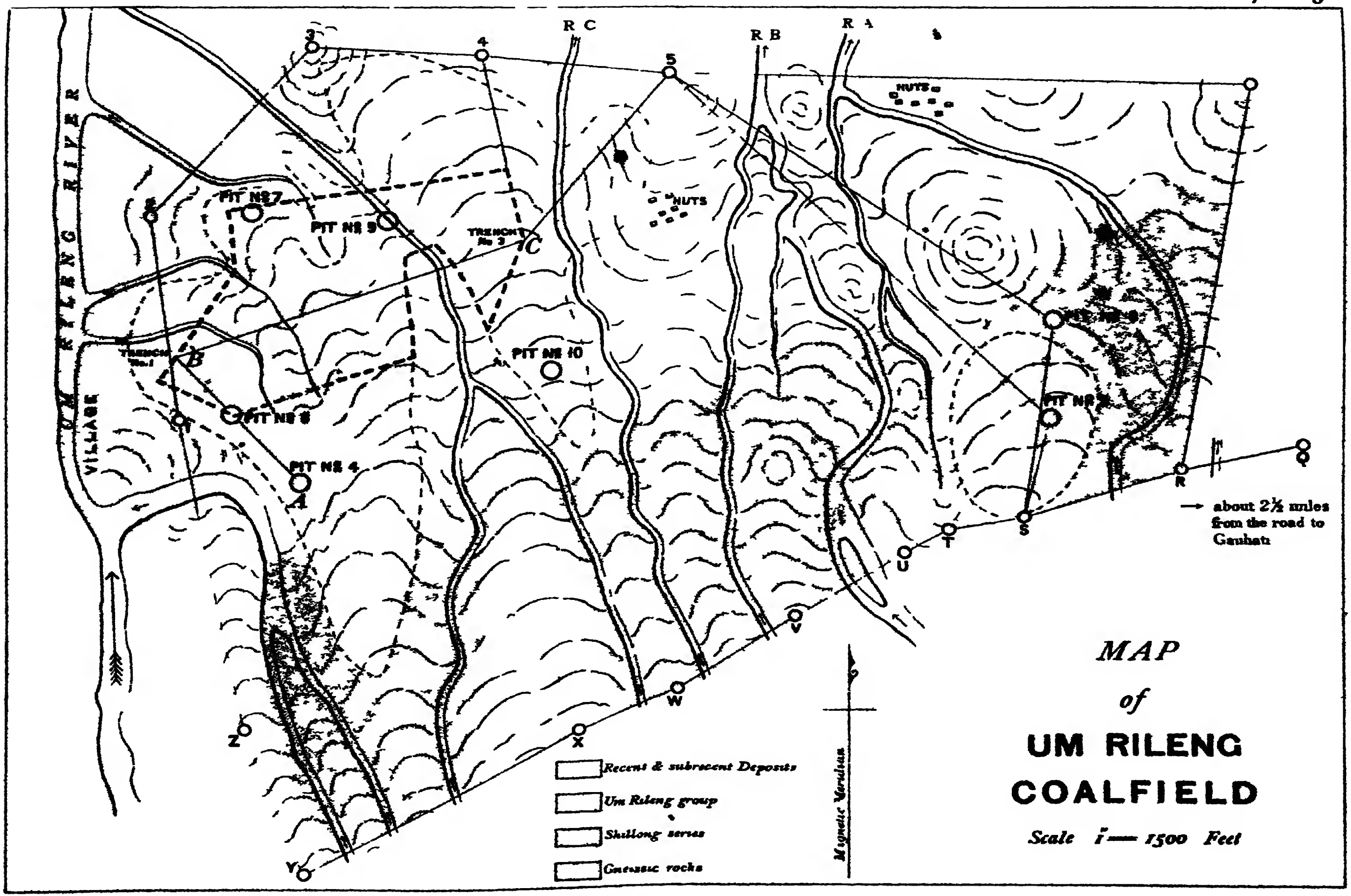
From two trenches (No. 1 on plan, and another about a hundred feet east of it) the following section was obtained, in descending order —

	Ft.	In.
Reddish loam with boulders (some of enormous size) and pebbles of "Shillong" quartzite . .	15	0
Soft sandstone and grits	10	0
Stiff clay with lenticular strings of coal . . .	3	6
Coal	4 to 5	0
Stiff, white clay	1	3
Dark, carbonaceous clay	2	0
Coal	6 to 6	6
Greyish stiff clay	1	2
Brownish sandy clay passing below into grits and conglomerate	3	0

Gneiss is exposed in the Um-Rileng river and its feeders just a little below the level reached by the above section.

The strata dip southward at about 6 degrees. But I am inclined to take the dip as local. The surface of pit No. 4 is at a height of 225 feet above the level of the surface of trench No. 1. If the hard sandstone at the bottom of the pit be the "Shillong" quartzite, then the base of the Um-Rileng group there is about 200 feet above its base at the trench, which would give a rise to the south of nearly 13 for every 100 feet. Besides, I found a small thin fragment of the Um-Rileng group with a thin seam of coal north-west of the Um-Rileng coalfield near the village marked as Maulum on the Survey map at a height of about 1,000 feet above the level of the coal at Um-Rileng. I am inclined to

[1] The plan has been made by Sub-Overseer Sukhlal Mitra.


UM RILENG RIVER
VILLAGE
PIT No 7
PIT No 9
PIT No 8
PIT No 4
PIT No 10
TRENCH No 1
TRENCH No 3
HUTS
HUTS
R C
R B
R A
→ about 2½ miles from the road to Gauhati
Recent & subrecent Deposits
Um Rileng group
Shillong series
Gneissic rocks
Magnetic Meridian
MAP
of
UM RILENG
COALFIELD
Scale 1" — 1500 Feet

think that though the strata roll about slightly (due probably to the inequalities of the surface of the older rocks on which they were deposited), their slope, if any, would be found to be northern, not southern. An adit which is now being driven close to trench No. 1 would throw further light on the matter.

From trench No. 2, the coal was traced eastward to pit No. 9, where it is no less than nine and-a-half feet in thickness, and thence to trench No. 3, a distance of 3,000 feet.

Assuming the coal to extend no further than 750 feet[1] southward, and to be confined within the trenches 1 and 3, its area becomes somewhat as outlined on the accompanying plan, that is, about 3,750,000 square feet. Leaving the upper seam of 4 feet in the section exposed by trenches 1 and 2 out of account, a thickness of 5 feet may be safely assumed over the whole of this area. We thus get 18,750,000 cubic feet of coal, or, making allowance for wastage, about 470,000 tons

Two samples of coal from the trenches 1 and 2 (taken close to the surface last season) have been analysed in the Survey laboratory, with the following results:—

	Trench 1.	Trench 2.
Moisture	16·02	17·36
Volatile matter	47·18	43·84
Fixed carbon	30·39	32·75
Ash	6·41	6·05
	100·00	100·00
Coking properties	Sinters slightly.	
Colour of ash	Light buff.	

Nests and strings of fossil resin occur in some profusion in the coal. There is also some iron pyrites.

[1] Pits 8 and 10 now in progress will, when completed, define the area more exactly.

NOTE ON A SAPPHIRINE-BEARING ROCK FROM VIZAGAPATAM DISTRICT, *by* C. S. MIDDLEMISS, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 4.)

So far as I know, the mineral sapphirine, though it has been repeatedly investigated chemically and physically, has until now been obtained from one source only, namely, Fiskernas on the west coast of Greenland, where it was originally found by Giesecke in 1809. It was subsequently described geologically by K. J V. Steenstrup,[1] chemically by J. Lorenzen,[2] and crystallographically and optically by Des Cloizeaux,[3] followed by A. Tschermak and L. Sipöcz,[4] Michel-Levy and A. Lacroix,[5] Stromeyer,[6] Damour[7] and N. V. Ussing.[8]

During last season's work in January 1902, I was fortunate enough to find a rock (registered number 15·808) in which the mineral is largely represented, and in association with other minerals in much the same way as in one of the varieties of the Fiskernäs rock.

The exact locality is 1½ miles S.-S.-W. of Páder or Páderu in the Madgul Zemindari of the Vizagapatam Hill Tracts, on the bridle road to Gangrez Madgul just beyond where the road crosses a little pass (lat. 18° 4′, long. 82° 42′ 30″, quarter sheet 93 S.-E., of the Atlas of India, 1 inch = 4 miles).

The rock occurs as a thin band or lenticular layer associated closely with a variety of pyroxene granulite (15·809), and in the neighbourhood of bands or lenticular layers of basic charnockite (norite) (15·738), all of which occur among a wide area of quartz-garnet-sillimanite-graphite schists of the upper gneissic or transition series, the so-called "khondalite" of Walker.[9] These latter are believed to be of metamorphic origin, whilst the pyroxene granulite and the norite are believed to have had an igneous intrusive origin. The

[1] Meddelelser om Grönland, VII, p. 15.
[2] *Ibid.*, p. 19.
[3] Manuel de Minéralogie, I, 402, and II, xlii.
[4] Zeitschrift für Krystallographie und Mineralogie, III, 512.
[5] "Les minéraux des roches," 277.
[6] Gilbert's Annalen, LXIII, 374.
[7] Bull. Soc. Geol. de France, 2), VI, 315.
[8] Zeits. für Kryst. und Min., XV, 1889, 596—605.
[9] Mem. Geol. Surv. Ind., vol. XXXIII, pt. 3.

foliation-strike of the sapphirine-bearing rock and the neighbouring rocks is about N.—S.

The rock is medium-grained, of a dark blue-grey colour varied by brown patches and the bronzy sheen of mica plates. It has a specific gravity of 3·24, and is finely and rather indistinctly foliated. Mineralogically it is a granulitic aggregate of rather pale hypersthene, which is the most abundant constituent; sapphirine, of deep blue-grey colour by incident light, and brown biotite, each in about equal proportions; and green spinel (hercynite), as large cores, nuclei or vermiform inclusions within the sapphirine.

In mineral association, therefore, it differs considerably from the more typical rock of Fiskernäs as described by Ussing,[1] which, in addition to the sapphirine, is composed of mica, gedrite and monoclinic hornblende with occasional cordierite, anorthite and kornerupine; and in which the sapphirine is developed as small, light-blue tablets, intergrown with the mica plates. On the other hand, it appears to agree very closely with the second type mentioned by Ussing and which he describes as composed of bronzite, sapphirine, dark-green spinel, a little light-brown mica, and perhaps pleonaste; in which the individuals show imperfect crystallographic outlines, the bronzite being placed idiomorphically in relation to the other minerals so that the latter only fill the angular spaces between the irregular bronzite crystals In this type also the sapphirine, as in my Vizagapatam rock, is distinguished by its darker colour.

On account of the very high specific gravity of sapphirine, and the relatively high specific gravity of the associated hypersthene, some ingenuity was necessary to separate sufficient of the sapphirine for a chemical analysis. The operation was skilfully performed by Mr. Blyth as follows: The rock was powdered and sifted, first through a sieve of 50, and then of 70, meshes to the linear inch, in order to obtain a uniform grain, the fine dust being rejected. After washing thoroughly the dried powder was thrown into Sonstadt's heavy liquid having a density of 3·2, in which the biotite floated and the sapphirine and hypersthene sank, the former going down first, showing it to be of the higher specific gravity. The separation of the sapphirine from the hypersthene was effected in Sonstadt's heavy liquid, crystallized and melted in a capacious test tube by being placed in boiling water to which some sodium chloride had been added in order to obtain a higher

[1] Zeits. für Kryst. und Min, XV, 597.

temperature—the melting point of Sonstadt's salt being 100° C. The molten Sonstadt's salt (having a specific gravity of 4·1) was diluted carefully with hot water till the hypersthene was found to float. When the two minerals had completely separated, the test tube was cooled rapidly by pouring cold water on it, and the molten liquid allowed to solidify with the separated minerals about two inches apart. The bottom of the test tube containing the sapphirine was broken off, the contents diluted slightly to allow all the broken pieces of glass to float, which were carefully removed, and the sapphirine then thoroughly washed.

About 5 grammes of perfectly pure sapphirine of a uniform grain was thus obtained. Its specific gravity taken with the ordinary S. G. bottle was found to be 3·539, the temperature of the water being 87° F. Its hardness was determined as 8, lying between that of quartz and topaz.

The chemical analysis was made by Mr. Blyth and gave the following results:—

	Including the hercynite.	Deducting the hercynite.
$Si\,O_2$	11·298	12·55
$Al_2\,O_3$	66·475	67·06
Fe O	18·156	16·21
Mg O	3·868	3·97
Ca O	·156	·17
Water lost at 100° C.	·224	·25
Loss on ignition	·491	·54
	100·66	100·75

It is insoluble in acids, and infusible.

As it was impossible to separate the enclosed hercynite, the method of weighing areas was adopted to obtain the proportion of this impurity to the mineral. I drew all the sapphirine grains and enclosed hercynite grains in two complete microscope slides by means of the camera lucida on paper, and weighed the relative areas. This gave the approximate relative volumes of the two minerals, from which their proportionate weights were ascertained to be—

H : S : : 1 : 8·719

which means that in 10 parts of the compound mineral 1 is hercynite and about 9 sapphirine. In deducting for the hercynite, the composition of it as given in Dana's Mineralogy (6th Edition) was taken.

The chemical formula, including the hercynite, works out to—

$$Mg\,O.\ 3\ Fe\,O.\ 7\ Al_2\,O_3.\ 2\ Si\,O_2.$$

and deducting for hercynite gives—

$$Mg\,O.\ 2\ Fe\,O.\ 6\ Al_2\,O_3.\ 2\ Si\,O_2.$$

Comparing the resulting analysis with those of previous observers as given below, the chief difference seems to be the replacing of part of the Mg O by Fe O :—

	Stromeyer.	Damour	Lorenzen.	Ussing.
$Si\,O_2$	14·3301	14·86	12·95	12·83
$Al_2\,O_3$	63·3036	63·25	64·44	65·29
$Fe_2\,O_3$ . . .	—	—	—	0·93
Fe O	4·0092	1·99	1·66	0·65
Mn O	0·5209	—	—	—
Ca O	0·3755	—	—	—
Mg O	16·9683	19·28	19·83	19·78
Loss on ignition . .	0·4924	—	0·34	0·31
	100·0000	99·38	99·22	99·79

Under the microscope in thin sections of the rock the sapphirine gives a biaxial figure in convergent polarised light. It is strongly pleochroic. In the sections which give the greatest colour change the pleochroism is—

𝔞 = very pale dirty orange or pinkish grey
𝔟 or 𝔠 = deep rich blue.

Many sections remain deep blue in all positions of the polariser, and there are no sections combining 𝔞 pleochroism with any other tint except deep blue. These all-blue sections give—

𝔟 = deep cobalt blue.
𝔠 = deep prussian blue.

The index of refraction must be fairly high, amounting to about that of the hypersthene in the same rock The interference tints in sections containing a and b or c are below those of the hypersthene in the same slide.

The sections showing b and c colours frequently show a tendency to elongation, with the long sides parallel to a single set of fine interrupted cleavage lines, giving extinction angles with c from 0° to about 25°. I found one all-blue section which in convergent polarised light gave a figure placing the plane of the optic axes parallel to the trace of that fine cleavage and so agreeing with the quartz-wedge tests placing a and c axes in that plane. If that single cleavage may be regarded as pinacoidal, the mineral must be monoclinic. Other irregular cracks making frequently large angles with one another appear in some sections.

I obtained no data for fixing the position of the optic axial plane with reference to the crystallographic axes.

To sum up the points determining the mineral as sapphirine we have—

(1) Its insolubility in acids, and infusibility.

(2). Its chemical composition which comes sufficiently near that of the typical sapphirine from Greenland.

(3) Its high S. G. = 3·539 (including the hercynite).

(4) Its hardness = 8.

(5) Its striking pleochroism and other optical characters, which agree with those of sapphirine.

(6) Its crystal system = monoclinic almost certainly

(7) Its association with other minerals, which is almost identical with that of one of the types of the Greenland rock.

EXPLANATION OF PLATE 4.

FIG. 1. Section of sapphirine-bearing rock (15·808), with polariser only.

s = sapphirine.
her = hercynite.
hy = hypersthene.
m = mica.

FIG. 2. Section of sapphirine grain, presumably in the orthodiagonal zone, showing fine cleavage traces parallel to c and giving b and c colours.

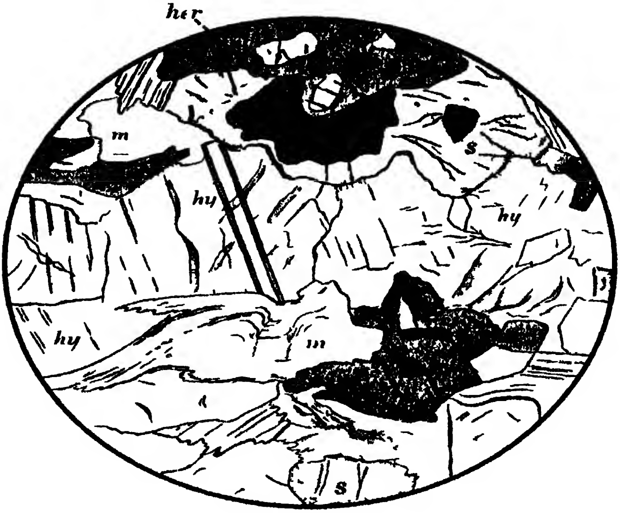


Fig 1 ×12

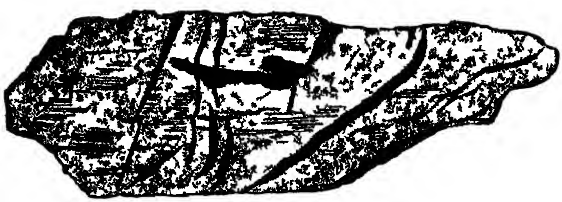


Fig 2 ×30

SAPPHIRINE-BEARING ROCK FROM VIZAGAPATAM DISTRICT

MISCELLANEOUS NOTES.

Tin-ore and Gadolinite in Palanpur.

A new locality for the tin-ore, cassiterite, was discovered in September last at Hosainpura, Palanpur State, Bombay Presidency, by Babu Baidyanath Saha, M A., Research Scholar. The mineral occurs in distinct, large crystals as a constituent of tourmaline-pegmatite together with the mineral gadolinite Both the isotropic and the anisotropic forms of gadolinite occur in the rock.

[T. H. HOLLAND.]

Tin-ore in Burma.

Interesting recent additions to the previous collections of tin-ore from Burma include a greisen containing cassiterite, obtained by the Conservator of Forests in Tenasserim, and various gravels rich in cassiterite and wolfram, together with samples of tin manufactured in the Bawlake State, Karenni, Southern Shan States.

[T. H. HOLLAND.]

Elæolite and Sodalite-Syenites in Kishengarh State.

Some specimens forwarded by Rao Bahadur Syam Sunder Lall, C.I.E., for determination in the Laboratory were found to include large fragments of blue sodalite from the neighbourhood of Kishengarh in Rajputana. Sodalite had hitherto been known in India only in small grains in an intrusive rock collected by Mr. LaTouche near Sarun on the eastern edge of the Barmer desert, which Mr. Holland found to be a tinguaite containing orthoclase, ægirine, sphene, melanite and sodalite in minute crystals. (*Mem., G. S. I.*, vol. XXXV, p. 92.)

As the unusual size of the fragments sent by the Diwan of Kishengarh pointed to an occurrence of quite exceptional interest, a special investigation of the rocks was made.

The sodalite was found associated with elæolite in some large veins of elæolite-pegmatite traversing a complex of elæolite-syenites, foliated in general conformity to the schist of the Aravalli series with which they are associated.

This is the third instance recorded of elæolite-bearing rocks amongst the older systems of the Peninsula, those previously recorded being the Sivamalai elæolite-syenite, described by Mr. Holland (*Mem., G. S. I.*, vol. XXX, p. 169), and some very similar rocks recently discovered by Mr. Middlemiss (*General Report, G. S. I., 1902-03*, p. 25), amongst the Vizagapatam hill-tracts. The presence of large masses of sodalite, some of them over a foot in diameter, amongst the elæolite-pegmatites adds a new feature of interest to the Kishengarh occurrence. Moreover, some of the sodalite exhibits an extraordinary phenomenon hitherto unrecorded in any mineral. While some of the specimens are of a bright blue colour similar to that of the mineral from many other localities, others appear under ordinary conditions transparent and colourless. But some of these colourless fragments when kept in the dark for a fortnight or three weeks assume a pink colour which disappears rapidly on exposure to bright day light, and almost instantaneously in direct sunshine.

The phenomenon is particularly brilliant when the rock is first broken in the field, and the large blocks of elæolite (some of which are over a yard wide) appear, on fracture, as if suffused with blood. The colour seems to re-appear more completely in some specimens than in others, for while the disappearance of the colour is very rapid, its re-appearance, which constitutes the most remarkable feature of the change, is very slow. The precise nature and cause of this peculiar phenomenon are at present unknown.

The following analysis gives the percentage composition of a specimen of the blue sodalite :—

Loss on ignition	0·82
$Si\ O_2$ (Silica)	38·055
$Al_2\ O_3$ (Alumina)	31·30
$Fe_2\ O_3$ (Iron sesquioxide)	trace.
$Ca\ O$ (Lime)	0·001
$Na_2\ O$ (Soda)	24·77
SO_3 (Sulphur trioxide)	trace.
Cl (Chlorine)	7·18
Less oxygen equivalent of chlorine	1·618
TOTAL	100·508
Specific gravity	2·27

The other variety exhibiting the curious change of colour has been found so intimately intergrown with elæolite that it is not possible to obtain a complete analysis. Partial analyses indicate, however, almost exactly the same percentage composition as for the blue variety.

The elæolite-bearing rocks are surrounded by scapolite-gneisses and all the syenites contain scapolite associated with the elæolite and sodalite. The elæolite-sodalite-pegmatite contains large crystals of ægirine, sphene and lime-iron garnet. Further details will be published in a future part of the *Records*.

[E. VREDENBURG.]

Gem sands from Ceylon.

Samples of sands and pebbles obtained by W. D. Holland of Dik Mukalana, Balangoda, Ceylon, included colourless topaz, corundum, zircon, spinel, chrysoberyl and pitchblende. Large crystals of allanite and specimens of the allanite-bearing rock were obtained from the same area.

[E. VREDENBURG.]

Gem sands from Burma.

Specimens of gravel from a tributary of the Ledawchaung, Katha district, Upper Burma, included spinel, sapphire, ruby, green and black tourmaline, zircon and topaz.

Rolled pebbles of rutile were obtained from Mohynin in the Katha district by Mr. C. M. P. Wright.

[E. VREDENBURG.]

Prehnite in Las Bela.

Specimens of this mineral, which is so far rare in India, have been obtained by Mr. R. Hughes-Buller, I.C.S., in the Kharari river, on the road to Bela, Baluchistan. The mineral exhibits the usual green colour and characteristic spherical aggregation; it is found to be intergrown with strontianite.

[E. VREDENBURG.]

Cretaceous fossils from Persia.

The specimens examined were sent by Mr. G. B. Reynolds, and were found some 10 miles east of Kila Sabzi, which is on the main road and telegraph line from Bagdad to Kerman Ghat, and is about 10 miles north of Khamkin on the Turkish frontier. The fossils include valves of *Gryphœa vesicularis*, Lam., representing an unusual variety with the posterior lobe indistinctly indicated, resembling the specimens described by Dr. F. Noetling from Mazar Drik in Baluchistan.[1]

There was also a form allied to *Ostrea Sollieri*, Coquand, and possibly specifically distinct. These fossils indicate a stratigraphical horizon of about campanian or the lower part of the upper senonian.

[G. E. PILGRIM.]

Ancient kitchen-midden in the Andamans.

A deposit found on the site of the Cadellganj barracks in the Andamans attracted attention on account of the presence in it of gold, in the hasty search for which most of the other valuable records were destroyed by the local authorities. The specimens collected and sent for determination included fragments of copper, rusted iron, teeth and bones of the Andaman pig, shells of *Venus* and *Arca*, quartz pebbles, fragments of ancient Andamanese pottery, lumps of resin, and grains, nuggets, melted lumps, and two coins of gold with illegible inscriptions in Arabic characters. The grains of gold included a small flake of platinum, suggesting a Burmese origin.

[T. H. HOLLAND.]

[1] The Fauna of Baluchistan, Pal. Ind., ser. XVI, vol. I, pt. 3, p. 39.

Note on the supposed locality "Sulgranees" whence Dr. J. E. Gray's type-specimens of Indian Jurassic Ammonites were said to have been obtained —In Mr. Crick's paper on Himalayan Jurassic Ammonites (*Proc. Malacol. Soc.*, V, pp. 285—289) the locality whence the specimens of *Ammonites Nepaulensis*, *A. Wallichii*, and *A. tenuistriata*,—the three species figured under those names by Dr. J. E. Gray in the "Illustrations of Indian Zoology," vol. i, pl. c,—were obtained, is stated, on the authority of the plate, to be "Sulgranees, Nepaul."

So far as I am aware, no such place as "Sulgranees" is known, and I may add that it is very doubtful whether the Ammonites represented in the "Illustrations" came originally from Nepal at all; it is more probable they were brought from further west, from the region whence Ammonites have been supplied to India in all probability for ages. It is certain that there has long been an importation of small Ammonites into India from the Tibetan side of the Himalayas, chiefly from the Spiti district, N.-N.-E of Simla, or from the neighbourhood of the Niti pass, north of Kumaun. These Ammonites, together with certain other stones, are known to Hindus by the name of "Saligram." I think it is probable that this name, slightly modified and written *Sulgranees*, has been mistaken for the locality of the fossils.

An explanation of the term *Saligram* will be found in Yule and Burnell's "Hobson-Jobson." The stones thus named are regarded as representatives of a god, and are especially connected with the cult of Vishnu.[1]

[W. T. BLANFORD.]

SELECTIONS FROM ASSAYS AND DETERMINATIONS MADE IN THE LABORATORY.[2]

Copper ores.

Antimonial tetrahedrite from the Southern Shan States, containing, besides the sulphides of antimony and copper, small quantities of arsenic, iron, zinc, lead and silver, the last-named amounting in one sample to 41 oz, 3 dwts. to the ton of ore.

Lead ores.

The following specimens have been determined :—Galena, one specimen containing 71·4 per cent. of lead and 5 oz. 11 dwts. of silver to the ton of lead; a second specimen contained 69·2 per cent. of lead with 8 oz. 9 dwts. of silver per ton. From Mehal, Abbotabad tahsil, Hazara district. Forwarded by the Commissioner and Superintendent, Peshawar division.

[1] (From *Proc. Malacol Soc.*, V, 345, 1903.)

[2] The assays and determinations here published are those considered to be of general interest and not hitherto included in published papers or in papers now in the press.

Galena from Riasi on the Chenab, in Kashmir State, contained 81·31 per cent. lead and 5 oz. 14 dwts. of silver per ton.

Arsenical pyrite and galena from Datgoti State, Simla district. No. 1 from Bhamla-nal, contained 8 oz. of silver and No. 2 from Basega-nal contained 9 oz. 9 dwts. of silver per ton of lead, with traces of gold (see *General Report, G. S. I.*, 1902-03, p. 14).

Galena from Baw-dwin Taung, near Taung-gaung, west of Taunggan, Shan Hills, contained 40·84 per cent. of lead and 4 oz. 18 dwts. of silver per ton. Galena from Nawkwo hill, Namlekok State, Southern Shan States, contained 67·9 per cent. of lead and 8 oz. of silver per ton.

Cerussite and minium from the Chandon Estate, 8 miles north of Baidyanath, East Indian Railway.

Manganese ores.

No 1. Kodaigaon, Nagpur District, collected by Mr. A. M. Gow-Smith. Analysis by L. L. Fermor, Geological Survey of India.

		Per cent.
Manganese dioxide	$Mn\,O_2$	56·72
Manganese protoxide	$Mn\,O$	30·83
Iron sesquioxide and alumina	$Al_2\,O_3 + Fe_2\,O_3$	3·94
Cobalt and nickel oxides	$Co\,O + Ni\,O$	·48
Silica	$Si\,O_2$	6·80
Baryta	$Ba\,O$	1·10
Magnesia	Mg. O.	Trace.
Combined water		·49
Moisture		·05
Phosphoric oxide	$P_2\,O_5$	·22
TOTAL		100·63

Equivalent to—

Manganese	Mn	59·73
Phosphorus	P	·007
Available oxygen		10·43
Specific gravity		4·504

The analysis shows that this ore consists, roughly, of two parts of braunite to one part of psilomelane.

No. 2. Mohugaon, Nagpur district, collected by Mr. A. M. Gow-Smith and analysed by L. L. Fermor.

		Per cent.
Manganese dioxide	$Mn\,O_2$	20·99
Manganese protoxide	$Mn\,O$	5·83
Iron sesquioxide	$Fe_2\,O_3$	1·99
Baryta	$Ba\,O$	·04
Strontia	$Sr\,O$	17·27
Lime	$Ca\,O$	18·63
Silica	$Si\,O_2$	3·47
Carbon dioxide	Co_2	27·46
Moisture		1·27
Combined water		2·86
Phosphoric oxide	$P_2\,O_5$	·12
TOTAL		99·93

Equivalent to—

Manganese	Mn	17·79
Available oxygen		3·86
Iron	Fe	1·39
Phosphorus	P	·051

No. 3. Conglomeratic grit cemented by psilomelane from Pala Khal in the Dhar Forest, collected by E. Vredenburg, and analysed by L. L. Fermor.

		%	
Manganese peroxide	MnO_2	28·84	Mn = 29 %.
Manganese protoxide	MnO	2·66	
Iron sesquioxide	Fe_2O_3	5·21	
Alumina	Al_2O_3	2·83	
Oxide of cobalt	CoO	·27	
Oxide of nickel	NiO	·56	
Baryta	BaO	6·84	
Siliceous residue		50·35	
Moisture		·75	
Combined water		2·50	
Phosphoric oxide	P_2O_5	·04	P = ·016 %.
TOTAL		100·85	

No. 4. Impure wad from the Bijawar rocks near Sontulai. Harda tahsil, Hoshangabad district, Central Provinces. Collected and analysed by Mr. Fermor, Geological Survey of India.

		%
Manganese dioxide	MnO_2	24·13
Manganese protoxide	MnO	1·96
Iron sesquioxide and alumina	$Fe_2O_3+Al_2O_3$	2·28
Cupric oxide	CuO	·47
Oxide of nickel	NiO	·38
Oxide of cobalt	CoO	·17
Baryta	BaO	·67
Magnesia	MgO	Trace.
Silica	SiO_2	69·18
Combined water		·88
Moisture		·53
Phosphoric oxide	P_2O_5	·03
TOTAL		100·63

Equivalent to—

Manganese	Mn	16·73
Phosphorus	P	·014
Available oxygen		4·44

Coal Assays.

Locality.	Collected by	Results of Proximate Assay. Moisture.	Volatile hydro-carbons.	Fixed carbon.	Ash.	Remarks.
Palana, Bikanir State	T. H. D. La Touche.	19·3	39·8	35·4	5·5	Does not cake. Ash light-brown.
Sohagpur coal-field, Rewa: Bagheha-Ambi seam—						
No. 1 from bottom	G. F. Reader. (*General Report, G. S. I.*, 1899-1900, p 69.)	6·56	28·04	51·00	14·40	Does not cake. Ash light-brown.
No. 2 „ „ .	Ditto .	8·16	29·04	49·40	13·40	Ditto ditto
No 3 „ „ .	Ditto .	7·36	29·84	48·00	14·80	Ditto ditto.
No. 4 „ „ .	Ditto .	5·76	20·84	38·60	34·80	Ditto ditto.
No. 5 „ „ .	Ditto .	6·56	30·24	41·40	21·80	Ditto Ash greyish.
No. 6 „ „ .	Ditto .	6·76	24·64	52·00	16·60	Ditto Ash brownish.
No. 7 „ „ .	Ditto .	5·76	22·64	53·20	18·40	Ditto Ash light-brown.
No. 8 „ „ .	Ditto .	5·36	24·84	48·40	21·40	Ditto ditto.
No. 9 „ „ .	Ditto .	5·96	22·84	47·60	23·60	Ditto ditto.
No. 10 „ „ .	Ditto .	5·56	21·04	47·20	26·20	Ditto ditto.
No. 11 . .	Ditto .	5·36	26·24	38·40	30·00	Ditto ditto.
Average . .		6·28	25·47	46·83	21·40	
Picked sample .	Ditto .	10·16	31·24	48·60	10·00	Does not cake. Ash brownish.
Son Bakahi seam—						
1st foot from surface	G. F. Reader .	2·56	18·84	51·40	27·20	Cakes feebly. Ash brownish-red.
2nd „ „ .	Ditto .	2·96	25·44	53·48	18·12	Ditto Ash brownish.
3rd „ „ .	Ditto .	3·36	28·04	57·40	11·20	Ditto Ash light-brown.
4th „ „ .	Ditto .	3·36	32·04	51·80	12·80	Cakes hard. Ash greyish.
Average . .	...	3·06	26·09	53·51	17·33	
Jamunia, west of Bichia—						
1st foot from bottom	G. F. Reader .	2·76	26·04	45·0	26·20	Cakes. Ash greyish.
2nd „ „ .	Ditto .	2·36	25·84	56·20	14·16	Cakes feebly. Ash light-brown.
3rd .	Ditto .	3·96	21·84	54·60	19·60	Does not cake. Ash greyish.
4th „ .	Ditto .	7·96	24·84	52·00	15·20	Ditto ditto.

Locality.	Collected by	Results of Proximate Assay. Moisture.	Volatile hydro-carbons.	Fixed car-bon.	Ash.	Remarks.
Rampur Bichia seam—						
1st three feet from the bottom.	G. F. Reader .	1·16	28·04	51·20	19·60	Cakes. Ash brownish red.
Upper seam . .	Ditto .	1·56	27·64	53·60	17·20	Ditto ditto.
Picked sample .	Ditto .	2·76	28·84	53·4	15·4	
Bageha Silpari, Ram Adhin seam—						
Upper portion of the seam.	G. F. Reader	6·56	30·24	53·40	9·80	Does not cake. Ash brownish.
Lower portion of the seam.	Ditto .	6·16	23 84	51·20	18·8	Ditto ditto.
Nargara Dhanpuri seam—						
Upper portion of the seam	G. F. Reader	6·76	24·64	60·6	8·0	Does not cake. Ash reddish.
Lower portion of the seam.	Ditto .	5·16	25·44	57·40	12 0	Ditto Ash brick-red.
Bageha Jhagraha seam.	G. F. Reader .	0·96	12·24	56·60	30·20	Does not cake. Ash greyish.
Bageha Sabo—						
No. 1 . . .	G. F. Reader .	3·56	24·24	53·00	17·20	Does not cake. Ash greyish.
No. 2 . . .	Ditto .	2·16	22·64	48 00	27·20	Ditto Ash brick-red.
Average . .	...	2·86	24·44	50·50	22·20	
Bakan seam—						
1st foot from surface	G. F. Reader .	9·56	20·04	32·00	38·40	Does not cake. Ash whitish.
2nd „ „ .	Ditto .	10·76	31·44	50·20	7·60	Ditto Ash brownish.
3rd „ „ .	Ditto .	10·16	26·64	53·00	10·20	Ditto ditto.
4th „ „ .	Ditto .	7·56	26·64	45·00	20·80	Ditto Ash light-brown.
5th „ „ .	Ditto .	4·56	24·44	40·40	30·60	Ditto Ash brownish.
Average of middle 3 feet.	...	9·49	28·24	48·24	12·33	
Bargaon-Kelhouri seam—						
1st foot from surface	G. F. Reader .	9·56	28 04	48·6	13·80	Does not cake. Ash light-brown.
2nd „ „ .	Ditto .	7·56	24·24	51·00	17·20	Ditto ditto.
3rd „ „ .	Ditto .	5·16	31 04	54·60	9·20	
4th „ „ .	Ditto .	7·96	30·64	53·80	7·60	

Locality.	Collected by	Results of Proximate Assay. Moisture.	Volatile hydro-carbons.	Fixed carbon.	Ash.	Remarks.
Katna tributary, south-east of Rampur—						
1st foot from surface	G. F. Reader	7·36	30·40	45·40	16 80	Does not cake. Ash brownish.
2nd " "	Ditto	5·96	23·64	49·60	20·8	Ditto ditto.
3rd " "	Ditto	...	...	...	..	Shale.
4th " "	Ditto	1 56	22·04	50 00	26·40	Does not cake. Ash light-brown.
5th " "	Ditto	1·76	24·44	51 2	22·6	Cakes partially. Ash light brown.
6th " "	Ditto	3·16	28·84	55·4	12·6	Cakes strongly. Ash brownish.
Average	...	3·56	25 88	50·52	19·84	
South-west of Birhuli	G. F. Reader	2 56	2·64	52·80	42 60	Does not cake. Ash dark-brown.
East of Kharla in the Kaser.	Ditto	1·56	2 64	43·60	52·20	Ditto Ash brownish.
Mati Jharna hill, Rajmahal Damin (lignite).	Sub-divisional Officer, Rajmahal.	8·56	23·04	51·20	17·20	Ash brown.
Sirgora village, Chindwara district, Central Provinces. (Pench river coal-field) 6′ 6″ seam, Malguzar's well, 28′ from surface—						
(1)	Manager, Warora Colliery.	15·83	33·71	42·18	8·28	Does not cake. Ash light buff.
(2)	Manager, Warora Colliery.	15·86	34·72	42·50	6·92	Ditto ditto.
18′ seam, No. 25 Pit, 3′ 6″ from surface—						
(3)	Ditto	12·54	31·08	37·41	18·97	Ditto ditto.
(4)	Ditto	15·5	32·15	42·22	10·11	Ditto ditto.
No. 8 Pit, 21′ 3″ from surface—						
(5)	Ditto	15·14	30·23	43·44	11·19	Ditto ditto.
(6)	Ditto	14·60	31·26	41·47	12·67	Ditto ditto.
Bore-hole No. 2, Ballarpur, 9 miles south of Chanda, depth 159 feet—						
No. 1	Manager, Warora Colliery.	7·0	16·1	50·1	26·8	Sulphur 0·73 per cent.
No. 2	Ditto	13·0	24·6	53·8	8·6	" 0·44 "

Locality.	Collected by	Results of Proximate Assay.				Remarks.
		Moisture.	Volatile hydro-carbons.	Fixed carbon.	Ash.	
Dhamtaur, about 6 miles from Abbottabad.	Engineer-in-Chief, Kashmir Railway Survey, Srinagar.	2'14	9'28	52'05	36'53	Does not cake. Ash light-brown.
Lashio coal-field, Burma: Outcrop No. 1, thick seam, upper portion.	T. H. D. La Touche.	19'84	35'72	34'84	9'60	Ditto Ash brownish.
Outcrop No. 1, thick seam, lower portion.	Ditto	21'58	31'90	31'08	15'44	Ditto ditto.
Outcrop No. 1, lowest 5' 6" seam.	Ditto	18'04	40'16	30'60	11'20	Ditto Ash brick-red.
Outcrop No. 2	Ditto	19'78	32'02	28'64	19'56	Ditto Ash reddish-brown.
Outcrop No. 3, 4' 6" seam, Napha stream.	Ditto	17'70	35'98	29'72	16'00	Ditto ditto.
Outcrop No. 4, 11' seam, Naleng.	Ditto	17'76	35'64	37'40	9'20	Ditto ditto.
Bed of the Mitaiphong nala, about 8 miles north-west of Diphu station, Nowgong District.	G. Ormerod (Superintending Engineer, A. B. Railway).	19'84	39'86	36'92	3'38	Ditto Ash dark red.

G. I. C. P. O.—No. 747 D. G. Surv.—17-2-1904.- 500.—J. Marum.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1904. [April.

LIEUT.-GENERAL C. A. McMAHON, F.R.S.

Since the last part of the *Records* was published Indian geolog and geologists have suffered an irreparable loss by the death of Lieut.-General C. A. McMahon, F.R.S., whose work in India, and, afte retirement in 1885, on Indian material, has advanced the science o petrology generally and not merely the problems of local interest.

The earliest of General McMahon's geological papers appeared i this publication as long ago as 1877, when he attacked the difficul stratigraphical problems connected with the unfossiliferous rocks i the neighbourhood of Simla, and foreshadowed, what he afterward proved by the unquestionable positive evidence of irruption, tha the so-called "central gneiss," in spite of its name and the the surviving professional prejudice, was but a deformed igneous intrusion McMahon was then a Lieut.-Colonel in the Indian Staff Corps an a member of the Punjab Commission. Taking advantage of furloug two years later, he went through a systematic training in the youn science of microscopic petrology, and on returning to India continue his researches on the North-West Himalayas, afterwards extending hi area of investigation by microscopic examination of various crystallin rocks of the Punjab, the Deccan Trap of Bombay, and the lavas o Aden.

For ten years after his opening paper in 1877, every volume of the *Records* included some of the results of his researches, in which he was continually opening up new fields by the addition of the microscope to the previous equipment of the Indian geologist. His work was more than a mere addition of data: his scientific activity broke down previously unsolved problems, leading sometimes to a modification of the recognised working hypotheses of the Geological Survey; and his twenty-four papers in the *Records*, besides being a monument to a great worker, are a testimony too to the liberality of the officer who was then responsible for the orthodoxy of the geological gospel in India, and who welcomed the truth from outside sources as much as that discovered by the official instruments under his direct control.

General McMahon served the first part of his career as a member of the Staff Corps in a Madras Regiment, and afterwards as a member of the Punjab Commission, retiring in 1885, when Commissioner of Lahore, after a service of 38 years.

On his retirement to England he took an active part in the work of the Geological Society, serving on the Council, from 1888, with short interruptions, until his death, and acting for some time as its Vice-President. At the same time he continued his petrological researches by investigations of the complicated problems of the Lizard peninsula in Cornwall, of the granite of Dartmoor, and of various material from India.

In 1894 and 1895 General McMahon summarised his views of the Himalayan crystalline rocks in his two Presidential addresses to the Geologists' Association; and in 1902, as President of the Geological Section of the British Association, pointed out the wider lessons of his researches in the same area. In 1898 he was elected a Fellow of the Royal Society, and in the following year the Geological Society of London marked the appreciation with which his work was regarded by conferring on him the Lyell medal.

Only those who had the privilege of his friendship knew the full extent of the genial, courteous, and generous nature which accompanied his ability and originality of character. Those who have had any experience of the controversies which naturally arise over scientific problems will understand the underlying character and methods of one of whom it can be said, with almost literal accuracy, that he found many antagonists but did not make a single enemy.

T. H. HOLLAND.

NOTE ON *CYCLOLOBUS HAYDENI*, DIENER, *by* PROFESSOR C. DIENER, PH.D., *University of Vienna.*

Among the rich variety of ammonites collected by the late A. V. Krafft and H. Hayden in the uppermost division of the permian Kuling shales of Spiti in the years 1898 and 1899, the genus *Cyclolobus* was represented by four species, namely *Cyclolobus cf. Oldhami*, Waagen, *C. insignis*, Diener, *C. Kraffti*, Diener, *C. Haydeni*, Diener. These four species have been described and figured by myself in Volume I, Part 5, of the "Himalayan Fossils" (*Palæontologia Indica*, ser. XV) Although our knowledge of the characters of *Cyclolobus* had been considerably enlarged by studying these materials, I felt obliged to confess my inability to give a complete diagnosis of any of my four species, either chambered nuclei of inner volutions or body-chambers of full-grown individuals alone being available for examination. My Himalayan materials being too precious, I was unwilling to sacrifice any specimen by destroying its body-chamber in order to develop its inner nucleus.

Cyclolobus Haydeni was the only species in which the two most important stages of development, chambered nuclei and full-grown individuals with body-chambers, were both known to me. On Plate VI of my above-quoted memoir views of both stages have been figured. Unfortunately, the sutural line of my specimens was too imperfectly visible to describe it in a satisfactory manner. Thus even in this species I was obliged to leave its description to a certain extent incomplete.

During his last season in Spiti, Mr. H. Hayden collected a few more ammonites from the Kuling shales, and he found among them the inner whorls of a small *Cyclolobus*, which in its external characters exactly corresponds with my type-specimen of *C. Haydeni* from Kuling (Pl. VI, fig. 8). After having succeeded in developing the sutural line, which he found to differ considerably from that of *C. Kraffti*, he sent me the specimen, together with my type-specimen of *C. Haydeni*, wishing me to add a note on the sutures to the description I had already written of the species.

Complying with Mr. Hayden's wishes I feel, however, bound to state, that the merit of the exact determination of the specimen and of the careful preparation of the sutures, a drawing of which (Fig. 5) has been made by means of the camera lucida, is entirely to his credit.

FIG. 5.—*Suture-line of Cyclolobus Haydeni, Diener. Enlarged by 4.*

The new specimen of *C. Haydeni*, from the Kuling shales of a nullah south of Pomerang, exactly agrees with my type-specimen from Kuling (Pl. VI, fig. 8) in all its external features. Both specimens are of similar dimensions, provided with a narrow, funnel-shaped umbilicus, and with three varices which run parallel to the lines of growth and are strongly bent backward in crossing the siphonal area. The measurements of the new specimen are as follows:—

Diameter of the shell		21·5	mm.
" " umbilicus		2	"
Height of the last volution.	from the umbilical suture	12	"
	from the siphonal part of the preceding whorl	6	"
Thickness of the last volution		13	"

Sutures.—The vertical projection of the periphery of the penultimate whorl touches the third lateral saddle in the last volution. Thus three lateral lobes and saddles are present in this species, exactly as in *C. Kraffti* and *C. Walkeri.*

In the details of the sutural line remarkable differences from the sutures of *C. Kraffti* are noticed. The principal lateral lobe, which in the latter species stands far behind the siphonal lobe in size and depth, is nearly as deep as, and only a little less broad than, the siphonal lobe. All the lateral and auxiliary lobes are distinctly tripartite, not bipartite, the central denticulation being deepest. Four auxiliary lobes and three saddles are noticed outside the umbilical suture. The outer branch of the siphonal saddle is very large and situated on a level with the inner branch, thus imparting to this saddle a decidedly bipartite character, as in *C. Walkeri.*

As has been stated in my memoir on the permian fossils of the Central Himalayas (p. 169), *Cyclolobus Haydeni* must be classed among the group of Cyclolobi, which, by the peculiar character of their siphonal saddles, differ from *C. Oldhami*, the prototype of the genus, and might perhaps be united in the sub-genus *Krafftoceras.*

THE AURIFEROUS OCCURRENCES OF CHOTA NAGPUR, BENGAL, *by* J. MALCOLM MACLAREN, B.SC., F.G.S., *Geological Survey of India.* (With plates 5 to 10.)

Introduction.

The gold deposits to be described under this head lie almost entirely within the area bounded on the east and west respectively by the meridians of 87° and 83° east longitude, and on the north and south by the 23rd and 21st parallels of north latitude, covering, therefore, about 20,000 square miles, and being included within the districts or native states of Mánbhúm, Singhbhúm, Dhálbhúm, Gangpúr, Bonai, Údepúr, Jáshpúr, and Raigarh. With the exception of the last-mentioned, all these territories lie within the Chota Nagpur Division. Gold occurs beyond this area, especially to the south and east, along the lower reaches of the large rivers which carry the drainage of the Chota Nagpur highlands, but in such small quantities as to be altogether negligible, even by the native washers.

Within the limits assumed above, it is by no means universally distributed, at least in quantities deserving of attention. The richest deposits appear to occur in the north of Singhbhúm and the south of Mánbhúm. Elsewhere the auriferous occurrences are few in number and poor in content. The eastern boundary is well defined by the Kushai River, but on the west there is no such natural boundary, and gold may be found anywhere in the neighbourhood of the rocks of Dharwarian age, until these, in the west of Jáshpúr and Údepúr, disappear completely beneath the Talchír shales and the Barákar sandstones.

With few exceptions, the visible gold occurs in alluvial sands, gravels, and conglomerates. The only auriferous veins on which work has been done in modern times are those at Sonapet, at Sausal, and at Pahardiah—all in Singhbhúm. From the degradation of these and of similar veins, the rivers draining the area, and notably the Máhanadi, the Bráhmini, and the Súbarnarikha, have received their alluvial gold, to be triturated and carried towards the ocean.

Natural features.

As might have been expected, the auriferous region comprises much of the mountainous country of Chota Nagpur. The ranges have a general maximum height of about 2,000 feet, a height exceeded in places by isolated peaks, and, in the Mánbhúm and Singhbhúm districts, by a solitary range of intrusive igneous rock, which attains a maximum of 3,050 feet. The ranges of the Dharwarian rocks present little diversity in character, their ridges generally coinciding with the strike of the strata. Their slopes are often steep and occasionally, as at Sonapet, the streams break through, by deep and narrow gorges, from subordinate lateral valleys into the main valley. In such cases the lateral valley may, by throwing a comparatively inexpensive dam across the gorge, be converted into a huge reservoir, the waters of which would often have a "head" of more than 250 feet. The gneisses and granites, the only other rock-formations of importance within the area, do not, as a rule, form mountain ranges, and occur, for the most part, beneath the wide alluvial plains of the lower reaches of the large rivers. Where, however, these rocks do rise above the level of the alluvial valleys, there are formed low, undulating hills, the rounded contours of which contrast very sharply with those presented by the high narrow ridges and deep valleys of the Dharwarian rocks. Occasionally, also, as at Sankra, near the Íb River, high rugged bosses of granite project above the surrounding plain, but these are never sufficiently numerous, nor of sufficient extent, to exercise the slightest influence in determining the flow of the water-ways of the country.

The rivers of the district are the Mand and the Íb, tributaries of the Máhanadi; the Sankh and the Koel, which together form the Bráhmani; and the Súbarnarikha, with its tributaries the Sanjai and the Korkai. All these have their origin in the highlands of Jáshpúr and Lohárdagá, to the north of Chota Nagpur. In their lower courses they flow through gravel plains, the bed-rock seldom showing; but in their upper waters, where they are still cutting down their beds, good exposures are the general rule. Especially is this so in the case of the Súbarnarikha, near Moholia Station, on the Bengal Nagpur Railway, where the river cuts somewhat obliquely across the strike of the upturned strata. In the mountain streams which feed these rivers a constant supply of water can be reckoned on only during the rains, and for about three to four months thereafter. To carry on extensive operations, such as those entailed by "hydraulicking," would therefore necessitate the formation of large reservoirs in the manner already indicated The ranges are covered with jungle, which, except in the more remote regions, is rarely dense. Since the line of the Bengal-Nagpur Railway is approximately that of the gold occurrences, the large timber near the latter is being, or already has been, cut out, thus certainly altering for the worse the conditions which lead to an equable flow of water in the streams.

History.

The earliest published reference to the gold deposits of Chota Nagpur is contained in a paper by Colonel Ouseley, read in 1839.[1] In this paper the gold washings of the Híra Khund, in the Máhanadi river a few miles below its junction with the Íb, are described with some detail. The gold washings of the Hodesum and the Kolehan tracts of Sínghbhúm are mentioned[2] by Lieutenant Tickell. It is not, however, very clear, from his description, to which portion of that district reference is made, but, in all probability, the sands of the Sona Nadi and of the Sanjai, then, as now, yielded the best returns to the washers. Colonel Ouseley, in a report to Government in 1847, enumerates a number of places in the vicinity of Rabkhob (Dharamjaigarh), in Údepúr, in which gold was washed at that time. In 1849 an examination of the gold occurrences of Jáshpúr and Údepúr was made by Robinson, who embodied the results of his journey in a letter, dated Ranchi, 20th December, 1849, to Captain Haughton, then Assistant to the Governor General's Agent in the South-West Frontier. This letter is published in the Journal of the Asiatic Society of Bengal, vol. XXIII, p. 103. Robinson describes with some fulness of detail the numerous shafts varying from twenty to sixty feet in depth, sunk so close together as to resemble nothing so much as a huge rabbit warren. Though he does not specifically mention Pharsabahal near the Íb river in Jáshpúr, yet there seems little doubt that it is to that place and to the mines in the vicinity to which he refers when he speaks of the "best mines." He further mentions the washing in wooden troughs ("dhuins"), the collecting of the soil, and the modified method of "hushing" or "booming," which is still practised at Pharsabahal, and assigns as reasons for the cessation of work which took place some time prior to his visit, the death of a number of people from the caving in of a shaft which had been carelessly widened below, and also the indifference of the then Rajah to the prosecution of the work. From certain

[1] Journ., As. Soc., Beng., vol. VIII, p. 1057.
[2] Journ., As. Soc., Beng. 1840, vol. IX. p. 694.

experiments made with native labour, Robinson came to the conclusion that these deposits could be made to yield a profit.

In the memorandum in which the above letter was transmitted Captain Haughton enumerates a number of auriferous localities in Singhbhúm. Here for the first time is mention made of Sonapet gold. "The metal was found some years ago in considerable lumps in the Sona Nadi of Sonapet in Tamar, on the northern extremity of Singhbhoom; and much is still found there; but the lucky man who got the 'nuggets' is believed to have kept his secret to himself. The gold of Sonapet is considered to be the best. The price varies from ten to seventeen rupees per tola . . . ."

In 1860 Dr. Emil Stoehr, in describing the copper deposits of Singhbhúm,[1] mentions incidentally the occurrence of gold in the heaps of slag from the copper furnaces worked by the ancients. This, however, amounted only to a trace.

An extended account of the Jáshpúr washings is given by Colonel T. Dalton in his notes of a tour in the Tributary Mehals, during 1863-64.[2] Though the precise locality is not indicated, these are probably the same workings as those visited by Robinson, fourteen years before, at Pharsabahal, near the Íb River. Since Dalton's visit, the industry appears to have languished, and there are now but few traces of the numerous shafts mentioned by him, while the number of gold washers is extremely limited, and they are the poorest of the inhabitants.

The examination of the rocks of Singhbhúm and Mánbhúm by members of the Geological Survey of India was commenced by Messrs. Ball and Ormsby in 1860. Eight years later a paper by the former was published,[3] giving the results of numerous trial washings for gold made during the previous season. He concludes that "the sub-metamorphics (Dharwarian) are between two-and-a-half or three times as productive of gold as the metamorphics" (granite and gneisses). This conclusion is hardly justified from such slender premises as those afforded by a comparison of the results of the washings of alluvial lying directly on each of the above rock-systems, for it would seem superfluous to point out that the alluvial gold so found need not necessarily be of local origin.

[1] Vierteljarhrsch. d. Naturforsch. Gesellsch., Zurich, vol. V, 1860, p. 329, and Neues Jahrb. für Min. Geo. u. Pal., 1864; translated in Records, Geological Survey, India, vol. III (1870) p. 86.

[2] Journ., As. Soc., Beng., vol. XXIV, pt. II, p. 51.

[3] "On the occurrence of gold in the district of Singhbhum," Records, Geological Survey of India, vol. II, pt. I, p. 11.

Mr. Ball again, in 1877,[1] reverts to the connection between the Dharwarian rocks and the occurrence of gold, and further advances the hypothesis of the possible derivation of the alluvial gold of the Ib River from the Talchír rocks, which are well developed in the vicinity. Attention will be given to this hypothesis in another place.

In 1881 the same officer published[2] a summary of the notes of previous writers on the subject of Chota Nagpur gold, adding thereto the results of his own investigations. Later in the same year appeared the first connected geological account of the rocks of the Division,[3] also from the pen of Mr. Ball. Hitherto, the auriferous deposits of Chota Nagpur had excited none but scientific attention, but in 1888, the discovery of rich alluvial specimens in the Sonapet Valley in the north of Singhbhúm, caused a little "prospecting" to be carried on in the neighbourhood, and the public excitement thus gradually aroused, culminated in a memorable "boom" some two years later.

A syndicate was formed to prospect the valley, and a report on the field was furnished by Mr. Bosworth Smith in July 1889. In the portion of this report accessible[4] no reference is made to the prospects of success before the syndicate, but the report is valuable as containing the first detailed geological description of the Sonapet rocks and quartz veins. During the following year, another geological report was furnished by Dr. Noetling, Palæontologist to the Geological Survey of India,[5] in which the origin of the gold and the possible returns from the alluvial deposits were discussed.

By this time Calcutta was in the throes of a "gold boom," none the less violent for their short duration. Before October of 1890 some fifteen or sixteen companies had been formed, comprising names—Patkūm, Patpat, Dhadka, Sonapet, etc.—that are even now only too well remembered. Within three months thirty-two companies with an aggregate capital of 151 lakhs of rupees, or a little less than a million pounds sterling, were in existence; large and valuable reefs were daily being discovered; great sums were squandered on useless mining machinery; and a paper specially devoted to the subject was published. In short,

[1] "On the Diamonds, Gold, and Lead Ores of the Sambalpur District," Records, Geological Survey of India, vol. X, pt. 4.

[2] Manual of the Geology of India, pt. III, p. 189.

[3] Memoirs, Geological Survey, India, vol. XVIII, pt. 2, "Geology of Mánbhúm and Singhbúm."

[4] "Gold, etc., in Chota Nagpur," King and Pope, Calcutta, 1891, p. 74.

[5] Records, Geological Survey, India, vol. XXIII, p. 73.

there were exhibited all those extravagances of opinion and of capital which always characterize the first "boom" in an agricultural or commercial community. All the while shares were being sold at many times their nominal value, confidence being to a great extent sustained by the monthly production of a small bar of gold from one mine. Early in 1892, however, it was accidentally discovered that the crushings of this mine, the only producer, had been systematically "salted" by certain persons connected with the local management. Hitherto, the conduct of prospecting and mining operations had been, with one or two notable exceptions, entrusted to those whose absolute ignorance of the subject was a guarantee of their freedom from dangerous prejudices, but, with the collapse of the above company, expert advice was sought, and being unfavourable, extinguished the last smouldering embers left by the raging fires of the "boom." By the end of 1892, there were not more than a couple of the numerous mining companies left, and these were dragging out a very precarious existence.

It is quite impossible at the present time to ascertain the true yield of the veins worked during the boom, if indeed any of the gold returned was native and not adventitious; but whatever the amount, it must have been very small.

Since 1892 prospecting work in Chota Nagpur has been spasmodic and of limited extent. A little was done by the Government of India in Mánbhúm during 1895, and a little by a private company some years later at Durjing, in the Bonai Native State. Both were resultless. Of late years attempts have from time to time been made to resuscitate the Sonapet companies, and a limited amount of work has been done on the gold-quartz veins of Pahardiah, near Anandapur, where a small "patch" of rich golden specimens was discovered.

Native methods of gold recovery.

Washing operations are carried on mainly during the rains, when water is abundant and is exercising in the stream-beds a certain amount of concentrating force, for the native washer concerns himself only with the gold at or near the surface. The actual operations are performed mainly by members of a section of the Gond tribe, known as Jhoras; but the Ghasis, who are generally considered to be among the lowest of the Kol tribes, also engage in the pursuit. In some places, *e.g.*, at Sonapet, the women alone wash, such labour being considered beneath the dignity of men. This is also the case near the Ib River, in the far west of Chota Nagpur, but there the gravels are very poor, being worth to the washer little more than a pice per diem. In the neighbourhood of Porahát the men alone wash, obtaining during the rains as much as three or four annas per diem.

The actual methods of gold recovery vary but little over the whole area. When the waters are low, work is conducted in the stream beds, a spot being selected where the numerous crev'ces between the boulders of a coarse gravel, and the consequent formation of eddies, have facilitated the deposition of the gold carried by the current. The boulders are thrown aside, and the comparatively small quantity of sand left behind is scraped up with some care, the operation being performed with a flat, pointed iron hook ("korne"), about 2 inches wide at its widest part. This hook is especially useful in scraping sand and gravel from a decomposed rock bottom, a practice invariably followed by the Jhoras. During the rains, when the streams are flooded, the sand concentrated in cart ruts and in the tiny watercourses on the hill slopes is collected and washed. In the Sonajori Nadi, at Pharsabahal, in Jáshpúr, the turf along the stream banks below flood-water level is also gathered for the same purpose. In this case, the grass and grass roots have served to entangle the gold, acting in much the same way as the cocoanut matting on the floor of a sluice.

The washing apparatus used in Eastern Chota Nagpur is simple and invariable in form, consisting merely of a shallow wooden tray (called a *patta—phara* in Bonai—and made from the wood of the Gumhari tree, *Gmelina arborea*, Roxb.), about 32 inches long and 16 inches wide, "dished" to a depth of two to two and-a-half inches. Those used by women and children are smaller, the size being proportioned to the individual. The larger trays enable about 40 lb. of gravel to be washed at a time. The dish when filled is placed in water about a foot deep, and the gravel thoroughly loosened and mixed under water, both hands being used. The varied movements thus imparted to the gravel enable the gold and heavier sands to sink to the bottom, leaving the coarse pebbles on the surface. These are thrown aside with a single sweep of the hand, as also are the uppermost sands, and the residues are treated much more carefully. Placing the left hand under the dish, the washer gives the contents a somewhat elliptical motion, taking care to use sufficient water, and sweeping off, from time to time, the lighter gravels as they come to the surface. When the sands have thus been sufficiently reduced, the dish, with its major axis horizontal, is tilted to one side, the residues are disposed to form as long and as narrow a band as possible, and water is carried with the right hand along the length of the small quantity that now remains, in order to expose any large grains of gold that may be present. Satisfied on this point, the washer rests the dish on the palm of the left hand and imparts to it a gentle reciprocating motion, at the same time causing, with the right hand, a gentle stream of water to flow over the concentrates. In the result a few yellow grains are left at the head of the trail of black sand. These are carefully transferred to a piece of a broken earthenware vessel, to be washed quite free from sand and to be melted into a small bead at the end of the day's work. When the washer has much fine gold, and when the waters are muddy as after rains, the Ghasis of Porahat (for the practice is not everywhere followed), in making a final separation of gold and sand in the potsherd, use an infusion of the leaves of a well-known climbing plant instead of water for that purpose. The plant is known variously to the Ko's as *Atinga*, *Utingi*, or *Atina*, and to botanists as *Combretum decandrum*. It is one of the commonest creepers of the neighbourhood, growing on the banks of every stream, and is easily recognisable by its white terminal bracts, and by its overpowering honey-like odour when in full bloom in January. As used by the washers, the *modus operandi* appears to be as follows:—Several leaves of the *Atinga* are rubbed between the hands until a greenish fluid is expressed, forming a copious lather with water. The froth having been removed, the liquid is poured into the potsherd, and a swirling motion given to the contents. The gold being thus collected in the centre, the potsherd is tilted to one side, causing the black sand to run in that direction. At the next instant the liquid is brought back and carries the gold in a collected mass before it. Certainly no mechanical operation could be neater or cleaner, and it appears to the writer that the complete success of the method is due as much to the dexterity of the operator as to any inherent property of the infusion.

The apparatus used in washing in the States of Jáshpúr and Údepúr differs somewhat from that described above, a shallow, tapering wooden trough, known as a "dhuin," being used. This is 4 feet long and 3½ inches deep, 18 inches wide at the head and 5 inches wide at the narrow or outlet end. The native raises the broad end of the dhuin so as to secure a good flow of water over the trough, places the gravel and sand to be washed at the upper end, and pours water over the sand from a peculiarly shaped vessel ("kari"), held in the right hand. The left hand at the same time is occupied in scraping the gravel to and fro until nothing but heavy black sand remains, the combination of motions of the right and left hands precisely resembling that employed in manipulating a digger's cradle. Near the narrow or outlet end of the dhuin are placed transversely one or two thin sticks which, acting as ripples, prevent the escape of heavy particles that may have been carried too far down the trough. When sufficient black sand has been collected in this manner, the further operation of separating the gold therefrom is carried on in a small tray, about 15 inches long and 6 to 8 inches wide, and twice as deep as a tray of similar dimensions would be in Singhbhúm, though the actual details of the further washing differ in no wise from those already described.

Beyond traditionary evidence, there is little to show that the auriferous deposits of Chota Nagpur were worked to any great extent by the "ancients." Such pits and shafts as they may have excavated in the course of their searches have long ago been filled to the surface, and their site is marked at the present time only by shallow depressions which, judging from external appearances alone, might with equal justice be referred to those left by the uprooting of forest trees. The obliteration of these old workings is extremely rapid. There is now but little sign of the deep pits seen by Colonel Haughton in Jáshpúr in 1863, and had their position not been exactly indicated by a native washer, who remembered them well as a boy, it would have been difficult to ascribe to the shallow depressions pointed out an origin other than natural. The native traditions of the quantities of gold obtained in past days are, of course, absolutely unreliable. Here, as elsewhere, wherever gold has been found, time magnifies the yield: grains become pennyweights, and pennyweights ounces. Only eleven years sufficed to multiply in the native mind the gold obtained by a prospecting party at Ankua one-thousand-fold. In the light of this natural tendency to exaggeration, the failure to obtain even a "colour" where ancient Rajahs, according to tradition, took away cartloads, is capable of a simple explanation.

By far the most interesting relics of the gold-seekers of bygone centuries are their rude stone implements for crushing, which lie scattered over many parts of Singhbhúm and Gangpúr. To these a considerable amount of attention has been given by Mr. F. H. Smith,[1] of this Survey, in view of their importance in indicating the spots most vigorously worked by the ancients and hence those considered by them the richest. The modern native washer has no explanation of the origin of these implements. To him they are *dev-log ke patthar*—the stones of the gods—and have fallen from the sky.

Mr. Smith distinguishes three forms of stones, each of which was used for a particular purpose. Taking them in the order in which they were probably used, the first comprises flat stones, 4 to 5 inches broad, 1 to 2 inches thick, and all showing on one side or the other, or on both, a saucer-like, more or less central, depression. There is little doubt that these stones were used for breaking the quartz into small fragments preparatory to further treatment, but it is not quite clear how they were used for this purpose. Possibly, as Mr Smith suggests, two of these were struck face to face, but it seems more probable that they were used singly, and as mortars, the operator placing the quartz in the depression and striking it with a hammer or with another stone. They indeed correspond exactly to the description given by R. B. Foote[2] of the ancient rock mortars used in gold quartz-crushing in Southern India. The stones generally used in this process were those which were ground flat in the later operation of reducing to powder the quartz fragments. The quartz, having thus been broken as small as possible, was transferred to a large, flat stone, from 1 to 2 feet in length and breadth. On this flat surface the fragments were ground to powder by attrition beneath a small, flat stone 4 to 5 inches broad, held in the palm of the hand as a muller, and to which a reciprocating motion to and from the operator was given. For all three forms of stone, compact, hard rocks—fine-grained diabase, or felsite, or quartzite—were preferred. As a result of continued grinding in a fixed direction, long, shallow grooves have been formed on the surfaces of the lower, larger stones. These grooves are generally about 18 inches long, 4 to 8 inches broad, and 1 to 2 inches deep. Since every suitable surface on each stone was utilised, it is by no means uncommon to find stones bearing two or three such grooves, each of the latter being successively abandoned as it became too deep for effective work. The small hand stones are correspondingly worn, presenting curved or flat surfaces according to the amount of attrition to which they have been

[1] Unpublished Progress Report, 1903.

[2] Records of the Geological Survey of India, vol. xxii, pt. 1, p. 35.

subjected, and the nature of the groove in which they were last worked.

These stones are not restricted to one locality, but are found in spots widely separated in Singhbhúm and Gangpúr, and generally in the heart of the jungle. Occasionally they occur closely grouped in flat, open spaces near water, when they probably mark the sites of the villages of the ancient gold-miners. In several places, many hundreds of grooved and worn stones are to be seen together, and from Rajabasa, to the south-east of Rourkela station, and from Katiar, 15 miles north-east of Goilkera station, Mr. Smith[1] reports more than a thousand at each place.

Near the scooped stones traces of old workings were almost invariably found, though often the amount of gold in the quartz and quartz shoadings would appear to be quite insufficient to account for the great numbers of grooved stones in the vicinity. The prospecting operations of the ancients were confined almost entirely to the "shoadings" (quartz débris) and to the outcrops of the quartz veins. The quartz of both was carefully broken to the size of a walnut, and, if one may judge from the numerous heaps containing absolutely barren white quartz, the fragments were carefully scanned for visible gold, while all ferruginous gangue stuff was put on one side for transport to the village or to water, where the further pulverisation and subsequent washing were doubtless performed by the women. In no case in Chota Nagpur, investigated either by Mr. Smith or by the writer, were deep ancient workings discovered comparable in the slightest degree with those of Mysore or even with those of the Wynaad. The deepest uncovered reached a depth of no more than 15 feet, an argument of no little importance when considering the potentialities of this region from an auriferous point of view.

Geology.

The geology of Chota Nagpur is extremely complicated, and as yet no further examination has been made than has been necessary to determine the broad structural features of the area. The most highly metamorphosed, though not necessarily the oldest, rocks of the region are gneissic granites and gneisses. These have a very extensive development in the north of Chota Nagpur, in Hazáribágh, Lohárdagá, and Jáshpúr; and also to the south towards Orissa. They thus

[1] Unpublished Progress Report, 1903.

surround almost completely the areas in which gold has been discovered. Within these latter areas, also, there is some development of the gneissic rocks. This is especially so to the east of Chaibassá, where the Kórkai River for the greater part of its course runs over gneissic rocks. In several places, and notably near Purulia, the gneisses are intruded by granite. Pegmatite veins, possibly contemporaneous with the gneisses, but probably later, are numerous in the schistose rocks of the western portion of the auriferous area, and are remarkable for the great size of their contained phenocrysts. Veins no more than two inches wide are found containing felspar crystals two inches in length. Of the nature of the gneissic rocks before subjection to pressure it is impossible to hazard even a guess, from the evidence presented in Chota Nagpur. Since, however, it would appear that the gneisses and allied rocks are in no wise connected with either the introduction of the gold to its present location or its deposition when introduced, it will be unnecessary for the purposes of this paper to further describe their lithological and other features in detail.

Dharwarian Series.—The great bulk of the rocks of the auriferous country must be assigned to the Archæan Dharwarian Series, formerly included in and known as the Transition Series, so largely developed in Southern Peninsular India. The correlation of the Chota Nagpur rocks with those of Southern India rests entirely, or almost so, on the correspondence of lithological characters, but this correspondence is so complete as to leave little doubt of their geological contemporaneity. The most prominent members of the series in this area are argillites, phyllites, mica-schists, talc-schists, and quartzites. The first and second appear to have their greatest development in the south of the region occupied by the Dharwarian Series, *i.e.*, in the south of Singhbhúm and the east of Gangpúr; while from the greater schistosity of the rocks of the series to the north, it is evident that there the agencies of metamorphism have been either more intense or have acted through a longer period of time. Speaking in general terms, it may be said that the amount of schistosity is inversely proportional to the distance from the granites and gneisses which bound the Dharwarian rocks on the north.

The argillites under the microscope show abundant evidence of having made considerable progress towards the phyllite stage. The individuals show marked orientation; the biotite mica, itself probably a product of metamorphism, has decomposed to form epidote; and the calcareous matter of the original sediments has reacted on the whole to form lime silicates, mainly omphacitic pyroxenes. Detrital granules of quartz, and possibly of magnetite, form a considerable portion of the mass. The schistose rocks of the north appear to have been originally much more aluminous, for there is in them a great development of chiastolite, crystals of which are exceedingly large and well formed at the Bandidih gorge, Sonapet Valley. At this spot are also found large crystals of staurolite, kyanite, and magnetite, the somewhat abnormal development of typical contact minerals and the greater schistose development being probably due to the proximity of an intrusive diabase (Dulma trap). The chlorite schists have in many places decomposed to potstone or impure steatite, which is worked into plates and similar articles by the natives.

Broad bands of quartzite among the schists are rare, but it is by no means uncommon to find thin bands intercalated with the argillaceous rocks. Mr. Smith[1] reports a peculiar green quartzite from Katiar, about 16 miles north of Goilkera. "The colour is chiefly "due to a great development of epidote at this spot, which mineral "is found permeating the rocks in all directions. The green quartzite "consists of a ground-mass of crushed granular quartz, in which are a "few sheaves of ragged actinolite with strings and scattered grains of "yellow epidote. Thin veins of epidote rock occur through the "quartzite, and also through trap-rock in the neighbourhood. It is "made up of large prismatic greenish epidote crystals set in clear vein-"quartz, with some actinolite and magnetite and leucoxene."

South-east of Rourkela towards the village of Mundaijodi, there occurs a rock of strikingly holocrystalline appearance, but which on microscopical examination proves to be of sedimentary origin. It is made up of large crystals of a pale-green amphibole and of pink garnet, both enclosed in a matrix of granular quartz. Accessory minerals, as sillimanite and epidote, are also present. There is little doubt that this rock represents an original impure grit or flagstone. Fragments only of the rock have been seen by the writer, but according to Mr. Smith[2] who found it *in situ*, it there forms a thin band of 8 inches, in the argillites of the Dharwarian series, and lying parallel with the plane of their foliation. The only other abnormal rock discovered in this series during the course of the survey was a band of serpentine

[1] Unpublished Progress Report, 1903

[2] *Loc. cit.*

near Raigara village, 13 miles north of Goilkera, running east and west in the strike of the enclosing strata. It is now much decomposed, consisting mainly "of patches of finely crystalline chlorite, irregu-"larly bounded by crushed calcite, with many scattered grains of "magnetite. Both the steatite rock and the fine matted chlorite "rock are quarried on a small scale by the natives, and worked into "bowls and dishes."

Except for a thick band of recent conglomerate lying directly on the granite in the Brahmini River at Durjing, there are no indications of either the prevalent jasperoid beds of the Dharwarian series in Southern India,[1] or of the jasperoid conglomerate, derived from the above, which generally lies at the base of the Cuddapah series.

Everywhere the rocks of the Dharwarian series stand upturned and on edge, their dip varying but little from the perpendicular. Hence, since a variation of only a few degrees is sufficient to effect the change, the direction of dip is extremely inconstant and affords little aid in the elucidation of the geological problems presented by the region. The strike is much more regular. In the south-west of the auriferous area, in Mánbhúm and Dhálbhúm, it has a general north-west and south-east direction, but as the rocks are followed to the north their strike is found to veer more and more to the east until it is due east and west, in which direction it continues until the west of Singhbhúm is reached. From thence the direction of strike veers still further, always in the same direction, until at the furthest limits of the series, in Jáshpúr and Údepúr, it is almost north-east and south-west, or at right angles to that in the extreme east of the area.

As one result of the season's work in Chota Nagpur, the boundaries of the Dharwarian series were extended considerably to the west and south-west, into the native states of Gangpúr, Bonai, Jáshpúr, and Údepúr. This area has heretofore been mapped as belonging to the gneissic and crystalline series. The greatest development of schistose rocks here lies along the Íb River and along its tributaries, mainly the Ícha. Though the gap of 20 miles lying between these rocks and those of the main Chota Nagpur mass was not bridged, yet the latter were brought down as far as Bamra, on the Bengal-Nagpur Railway,—so far indeed as to leave little doubt of the continuity of the Dharwarian series from Simlapal, in Bankura, where the alluvium of the Gangetic valley obscures the further eastern extension, to at least the

[1] Records, Geological Survey, India, vol. XXI, pt. 2, p 40.

boundary of the Údepúr State, a distance of 180 miles. The maximum breadth of the band is probably about 50 miles.

Cuddapah beds.—From near Jaraikēla to Bamra, and parallel with, and at a distance of one to three miles from the Bengal-Nagpur Railway, is a series of sandstones, grits, shales, limestones, the first containing in places highly ferruginous deposits. The dip of the whole is extremely high, and is generally to the south. Near Raganathpali, these beds are exposed in the bed of the Koel River, where they are composed of sandstones and shales and of grey compact limestones, all dipping to the south at angles of 60 degrees and over.

The limestone band is extensively worked at Bisra and at Rourkela by the Bengal Stone Lime Co.—formerly the Bisra Stone Lime Co.—the limestone being brought by tramways to the railway stations and there burned. The hæmatite deposits of this series occur in fine sandstones, and are now being examined by the agents of a powerful company with a view to their exploitation should economic conditions permit.

At Durjing, in the Bonai State, is a series of sandstones, shales, quartzites, and conglomerates—the latter containing quartzite, gneissic, and sandstone pebbles—which are probably to be correlated with these of Rourkela and Bisra. Of the age of these latter beds, Mr. Smith, who has examined the Cuddapah Series elsewhere, says[1]:—"The sandstone and grit is of a peculiar grey-greenish colour, and "it strongly resembles the lowest Cuddapah bed in the Barapahars, "to the north-west of Sambalpur. The whole facies of the rocks of "these two localities is very similar, and it seems probable that the "Bisra belt is a band of Cuddapah age, which has here become folded "into the underlying transition rocks."

Igneous rocks intrusive into the Dharwarian Series.—The oldest of these are probably the pegmatitic veins of the Ícha River and its neighbourhood, in the west of Gangpur. They are there very numerous, and lie intercalated along the planes of schistosity, are rarely more than a foot, and are generally from one to two inches in width. All show the remarkable phenocryst development characteristic of Indian pegmatites. The constituent minerals show a regular arrangement, the orthoclase on the walls, and the quartz, muscovite mica, and accessory minerals in the middle of the vein; an arrangement arising, no doubt, from the greater solubility of the

[1] Unpublished Progress Report, 1903.

micas, etc., in the vein magma, rather than from any influence exerted on the magma by the vein walls, for the latter show, beyond a slight induration, little evidence of contact metamorphism. Though alluvial gold does occur in the neighbourhood of these pegmatitic veins, there is no evidence whatever to connect them with the deposition of the gold.

The younger intrusive igneous rocks are more basic in character. They are developed mainly as a long, narrow band running from near Dhádka in Mánbhúm, crossing the Subarnarikha River south of Chandil, and turning to the west, where they were traced as far as the South Koel River. It will thus be apparent that the band lies parallel always to the strike of the enclosing rocks. The igneous rock itself is invariably dark-coloured, and is thickly studded with crystals of an amphibolitic mineral. Sometimes the latter occur to the almost complete exclusion of felspathic matter, when the rock becomes practically a massive hornblende.

Under the microscope the amphibolitic mineral is seen to be actinolite, but there is also a great deal of obviously secondary hornblende present, some of it showing ophitic structure. No pyroxene is discernible in any of the sections. The felspars have all been reconstituted, and their original form is lost. Accessory minerals are epidote, zoisite, magnetite, and the decomposition product, leucoxene. From the above it will therefore be apparent that the rock must be termed either an epidiorite or a proterobase, according to whether the hornblende is regarded as wholly or partly secondary.

As already remarked, the schists in the vicinity of this intrusive rock show many evidences of extensive metamorphism, much of which is to be ascribed directly to the influence of the diabase magma. The characteristic contact minerals, chiastolite, staurolite, kyanite, etc., are largely developed in the immediately adjacent strata, while a little further away the rocks show marked increase in schistosity or in induration, according to their nature.

Further exposures of the diabasic rock occur north-east of Chaibassa, and near the Rajdoha copper mines, and in numerous scattered localities, occurring generally as thin dykes intercalated among the schistose rocks.

The importance of this igneous rock lies in the probability of its intimate connection with the deposition of the gold, an hypothesis to which attention will be given in another place.

Quartz Veins.

Throughout the Dharwarian Series in Chota Nagpur quartz veins are everywhere abundant, their white shoadings forming a characteristic feature of many landscapes. Widespread silicification—an almost necessary concomitant of the kaolinization to which the felspathoid members of the sediments have been subjected—and the tendency of these rocks to yield to stress by innumerable small fissures rather than by major faults, appear to have resulted in the formation of numerous thin veins, limited in extension both horizontally and vertically, rather than in the production of true fissure lodes or master veins. The only possible exception to this generalization known to the writer is furnished by the large quartz lodes of Ankua, south-east of Manharpur, and of these there is only evidence of horizontal extension. It appears also to be possible to separate the quartz veins into two main groups, an older and a younger, distinguished partly by differences in colour and mineral content, but mainly by the relative amount of disturbance to which they have been subjected. The older generation of quartz veins was formed before the final upheaval of the schists, and give by their extremely fragmentary character some conception of the enormous amount of deformation these beds have undergone. Veins of this generation have little continuity, and are now generally represented by a line of scattered quartz patches, the members of which are often lenticular in form and as often, in obedience to a general lateral pressure, showing marked orientation. Silicification had obviously ceased prior to the formation of the faults which were necessary to the dislocation and subsequent orientation, for of these fissures no vestige remains. The quartz itself of the older veins is blue or white, generally translucent, and resembles much in character the authigenous quartz of the plutonic rocks. To this type of vein the pyritous portion of that worked at Pahardiah[1] must be assigned. There, however, a later deposition of silica has taken place which tends to obscure the lenticular character of the quartz deposits, a character which is further obscured by the contact of the vein at several points with the quartzite beds of the vicinity. This occurrence is invested with a certain amount of importance, inasmuch that it is, so far as is known to the writer, the only older vein which could be

[1] Memoirs, Geological Survey of India, vol. XXIII, pt. 2.

considered to contain gold in appreciable quantities. That this occurrence of gold in an older vein is only apparent, will be shown later. Several very rich auriferous specimens, reported to be from this vein, are in the Indian Museum, Calcutta, and after a careful comparison of specimens recently obtained from Pahardiah, little doubt remains that they have actually come from the spot indicated on the label.

The younger generation of quartz veins differs from the above in that the quartz is white and opaque, and their continuity has, of course, suffered little in comparison from the dislocations arising from orogenic movements. To this generation belong the huge "buck reefs" of the country. These, from their greater resistance to the agencies of denudation, are often found, as at Ankua, along the crests of hill ridges, and have there often a width of 40 feet. In length they are extremely irregular, being in places no more than mere "blows," or quartz deposits of indefinite shape. Contemporaneous, also, are the small thread-like quartz veins that lie generally conformable to the plane of foliation but occasionally breaking their way across to other veins by transverse fault lines. The quartz of these small veins often shows endomorphic structure, the endomorphs being as a rule coated with hæmatite and limonite.

During the season's work a certain amount of attention was paid to these younger veins, as they appeared to furnish by their degradation the greater portion of the alluvial gold of the district, and of them, the veins opened up at Sausal, 10 miles north-west of Goilkera station, appear to be so fairly typical of the others that a description of them will serve for the whole. The accompanying sketch plan (Plate 6) will give some conception of their tenuity, poverty and irregularity. Attention was first directed to them by the existence of small pits and trenches indicative of old workings On opening these up, it was found that the "ancients" had followed, along the hill-ridge, a major joint plane, and at first the object of their search was not apparent. The discovery, however, of several cross leaders carrying argentiferous galena, and, in "vughs" and cavities, a small number of specks and grains of gold, made it evident that the latter had been the metal for which they had mined. The leaders were extremely thin, varying from 1 to 5 inches in thickness. Their strike was almost due north and south, but extremely irregular in extension, persisting in some cases for no greater distance than 12 or 14 feet. The quartz was white and opaque, stained with ferruginous matter, and containing, when auriferous, small patches of galena. It is from the vicinity of the galena occurrences that the golden specks and grains have invariably been obtained. Some of these veins, even when showing nothing to the eye, on crushing and washing, yielded a few extremely fine "colours." These, from the proximity of the veins to the surface, may, however, have been derived from the overlying soil, and may not have had in their origin any connection with the vein in which they were found.

On washing and panning the galena lodes, it was found that they were always auriferous, the highest samples showing about 2 dwts. to the ton. It is quite certain, however, that a single ton would contain all the available quartz of this description in sight, and that from these veins there is no hope of profitable return.

Mr. F. H. Smith, of the Geological Survey, devoted a considerable amount of attention during the cold seasons of 1901-02 and 1902-03 to the valuation of the quartz veins of Chota Nagpur. The method of assay adopted by him was simple, but, considering the nature of the gold, quite efficacious. The vein was sampled and a large quantity crushed to pass through a 25-mesh sieve, weighed, and washed carefully by a native washer in his wooden tray, the remaining gold collected and weighed. For coarse gold, when quantities of 40 to 60 lbs. are taken, and when pyrities or sulphides are absent, this method is far superior to any fire assay, in which only a few ounces are taken and in which the presence or absence of a single large grain may give quite erroneous results.

During the last season Mr. Smith made no less than 211 of these assays, from nearly 200 separate reefs in the neighbourhood of Sausal, of Porahat, of Sonapet, and of Rourkela. Of these 211 crushings—

108 yielded no gold,
59 " minute traces,
43 averaged ⅔ dwts. per ton, and
1 yielded 17 dwts. per ton.

The last comparatively high yield was due to the presence of an exceptionally large grain of gold, and further trials from the same vein and in the immediate vicinity showed only normal results.

These figures correspond very closely with those obtained in the previous season's work, and while they afford ample explanation of the ubiquity of the alluvial gold, are far from encouraging when considering the potentialities of Chota Nagpur reefs.

There is a remote possibility of some of the quartzites, found, as already remarked, in thin bands in many places, being auriferous. About 1890, a native gold washer discovered in the Loradari stream, north-west of the village of Burndabon, near Goilkera, a large, highly auriferous quartz specimen. According to the description of the finder, it weighed from 50 to 70 lbs., was somewhat smooth at the angles, and was black in colour. A small portion of it, estimated to contain two tolas (15 dwts.) of gold, was sold to a European, but the greater part of it was taken to the village and there crushed and washed for a handsome yield. When the spot was visited by the writer, the native gold-washer who made the "find" was asked to select from the stream-bed a stone precisely similar in appearance to that which had furnished the gold. After a little search he produced a stone which he averred was precisely similar—a statement corroborated by his companions, who had all seen the original stone, and who had spent many weeks in the fruitless search for more auriferous specimens. On examination, the stone produced was seen to be, not a quartz fragment, but a friable quartzite, stained almost black with manganese and iron oxides, and obviously derived from one of the many thin quartzite bands that seam the country higher up the valley. The specimen selected by the native was crushed and washed, but without result.

Character of Vein Gold.

The salient feature in the occurrence of gold in the veins of Chota Nagpur is the complete independence of gold and of quartz. In no case, except in that of Pahardiah—and even this exception, as will be seen below, is only apparent—does the gold occur surrounded by, and embedded in, the vein stuff. Everywhere else it is found as minute specks and grains, showing more or less tendency to crystallization, lying on and adhering to the ferruginously stained faces of the quartz crystals. It particularly affects small "vughs" in the vein; whether from the fact of these affording suitable spots for deposition, or whether the gold now found in these cavities is that which was originally contained in the galena and other sulphides which formerly occupied the vugh, is not clear. In all probability the latter is the true explanation.

An examination of the highly auriferous specimen from Pahardiah, now in the Calcutta Museum, at first seemed to furnish conclusive proof that here, at least, was a case in which the gold and quartz were of contemporaneous deposition. A closer examination, however, showed that the contemporaneity was only apparent. The main body of the specimen is a bluish gray, somewhat translucent quartz, plentifully besprinkled with small cubical crystals of iron pyrites, the latter, so far as can be seen, contemporaneous with the blue quartz. Through the middle of the specimen runs a thin vein of white, opaque quartz, carrying no pyrites, and it is on one wall of the thin white vein that the gold is disposed. The history of the specimen, with these facts in view, becomes fairly clear: the rock was fissured, the blue quartz vein formed and subsequently fractured, and gold deposited along the open fissure before the formation of a necessarily much younger vein of white quartz. The importance of this fact, and the perhaps not very obvious necessity for laying stress on the invariable association of the gold with the younger generation of quartz veins, and on the deposition of the former, almost invariably subsequent to that of the latter, will become apparent when it is stated that therein lies the great distinction between the auriferous veins of Chota Nagpur and those in similar rocks in the Kolar field of Mysore. In the latter case the auriferous veins are old and have shared in the plication of the country rock, and the gold is mainly of contemporaneous deposition.

Deposition of Gold in the Veins of Chota Nagpur.

While, generally speaking, it can serve no useful economic purpose, especially in the absence of comprehensive data, to set up an elaborate theory to account for the origin of Chota Nagpur gold, there are yet several points of theoretic interest which have an indirect bearing on the economic side of the question. Of these the similarity of the auriferous rocks of Chota Nagpur to those of the Kolar field, the poverty of the former, and the richness of the latter, are the most important. To the writer, with the very limited evidence before him, it would appear that the matter resolves itself, in the latter respects, into a question of age. On the Kolar field, dynamic metamorphism has been intense. The rocks, whether originally igneous or sedimentary, have lost almost entirely their primary lithological characters, and have, in the case of those immediately in contact with the quartz veins, been converted into a hornblende schist which has retained its constituent minerals nearly as clear and as fresh to-day as when they first

[1] Progress Report, 1903.

crystallized, thus proving that never, at least since their formation, has hydro-metamorphism been active in the Kolar district. It therefore follows that, with the absence of hydro-metamorphism, the development of silica and consequently of siliceous veins could not have been extensive, and we are thus forced to ascribe to the large quartz veins of the Kolar field an origin not long subsequent to the final crystallization of the phenocrysts of the adjacent schists. This view gathers some support from an examination of the quartz veins themselves, which have certainly participated in the later movements to which the rocks have been subjected, and, in a lesser degree, from the general distribution throughout the vein quartz of innumerable minute vesicles, pointing, it would seem, either to an original viscous or to an original colloidal form of silica. Further, an examination of the vein quartz leaves little doubt of the contemporaneous deposition of the gold and quartz. It is well established that a soluble compound of gold is formed with an alkaline silicate, and from the writer's work in that direction, he is inclined to ascribe to silicic acid and to the alkaline silicates the honour of being the sole solvents of gold, whether metallic or as a telluride, *below the level of oxidised and oxidising waters.* And adopting silicic acid as the chief solvent of gold, it at once becomes apparent that the almost invariable association of gold and quartz is not fortuitous, but is a result of their prior chemical affinity, and the theory also explains the general simultaneous deposition of matrix and of content, though, for reasons arising from the relative rapidity of deposition of quartz and gold, these are rarely deposited *pari passu.*

Turning now to the Chota Nagpur field, it will be found that while over the whole area of the Dharwarian rocks neither dynamic metamorphism nor deep-seated hydro-metamorphism were more intense than on the Kolar field, there are yet local and restricted areas in which both were more active. It is certain that the Dharwarian series in this area has suffered far less from orogenic movements than similar rocks further to the south, for it has already been pointed out that the sedimentaries in the south of Singhbhúm have reached no further than the phyllite stage, and some indeed not so far. It is only in the neighbourhood of the great masses of diabase or epidiorite (Dulma trap) that metamorphism has prevailed to any great extent, and it is clear that this is local and is due merely to an intrusion of igneous rock.

From the nature of the Chota Nagpur quartz it is probable that it is the result of the decomposition by meteoric waters of the felspathoid minerals of the schists, phyllites, and argillites, and is therefore of comparatively recent age, to which conclusion we are also led by the undisturbed condition of the veins. Of whatever age these may prove to be, it is at least certain that their growth was completed prior to the deposition of the gold. Looking round for a possible cause for the renewal of energy indicated by the auriferous deposition, we are at once confronted with the diabase rock. Of its age it is impossible to say much, except that it probably belongs to the Cuddapah series, for its crystals show signs of having suffered a considerable amount of deformation, and a tendency towards incipient schistosity. All things considered, we are brought to the conclusion that the deposition of the gold in the veins resulted from the intrusion of this diabasic rock, but as to whether the auriferous solutions were brought from below with the igneous magma, or as to whether the magma simply furnished the solvents that, on percolation through the adjacent presumably sedimentary rocks, caught up their already contained gold, we have at present no clue. Nor have we more knowledge of the nature of the solvent, except that it was certainly not silicic acid, for in that case the gold would be contained in silica, instead of being deposited in open cavities; and further, the general association of gold and galena dimly indicates a sulphide solvent. However, as already remarked, generalization in the absence of data is useless, and nothing more detailed than the above can be said until the completion of minute analyses and assays of the igneous rock of the schist, of the phyllite, of the quartz, and of the galena, for microscopic quantities of gold and for evidences of chemical and of crystalline change.

Deposits of Alluvial Gold.

In considering the auriferous alluvial deposits of Chota Nagpur, the salient features with which we are confronted are (*a*) their wide distribution, and (*b*) their comparative uniformity of value. In few auriferous countries elsewhere, so far as the writer is aware, can colours be obtained so readily and varying so little in number and in size. Indeed, the occurrence of gold grains, generally so useful in tracing the metal to its parent source, is here so universal, that any attempt at this method of prospecting is doomed to certain failure. The prevalence of loose surface gold also tends to error in the estimation of the values of quartz veins, for the latter, when open to the surface, receive from the soil many gold grains, which are indistinguishable from those actually formed in the vein, since, as has already been seen, the latter are loose in cavities, or are but loosely embedded in a ferruginous matrix.

The wide-spread and uniform distribution of alluvial gold arises, in the main, from two causes. In the first place, the vein gold occurs in localities far apart, but far more important is the mechanical influence exerted by the character of the surface rocks and by the nature of the "rains" Both the latter are extremely unfavourable to concentration of gold in river and stream beds, with the ultimate formation of those rich "leads" which are the object of alluvial mining in California, Victoria, and New Zealand. The Dharwarian rocks, as already remarked, are everywhere upturned and on edge, and their schistosity presents an interminable succession of crevices over which grains of gold cannot readily pass. Such gold as does find its way into the river beds is not concentrated there. The torrential character of the streams during the "rains" precludes the possibility of the concentration observable in streams in temperate regions. Even if by any combination of circumstances a fairly rich "lead" were formed in any one season, the flood waters of the next rains would certainly scatter its contained gold through many cubic yards of detritus.

For the same reason, there are no "leads" through the alluvial flats, and no "bottom runs" of gold. There is certainly a little concentration on the "bottom," but this arises solely from the high specific gravity of gold, and its consequent tendency to settle in water-logged gravels. That this is no very potent factor is evident from the writer's operations in the Sonapet valley, where the mass of the alluvial tested yielded from 1 to 1½ grains per cubic yard, while the six inches or so of the gravel resting on the bottom returned no more than 2 grains per cubic yard.

The gold washed by the natives is procured from the stream beds by the treatment of sand scraped from between and under the coarse pebbles and boulders found on the surface of the stream gravel. The slight concentration observable here arises from the retardent action exercised on the current by the large boulders and stones, which, in fact, act precisely as "riffles" in a tail-race. Concentration of gold is therefore only effected during the subsidence of the flood waters, but so little is it that, even at the most favourable spots in the best rivers and streams, the native washers, with hard work, rarely make more than 3 annas per diem.

Of these favourable spots the most frequented are at Patkum and along the Subarnarikha River; in the Sona Nadi at Sonapet; and at and near Porahat, on the Sanjai River. The last mentioned appears to support the greatest number of washers, and though they speak of earning large sums (for them), they were very eager to work for the writer at 4 annas per diem. Their average earnings must consequently be much less. In other places, the washers are so poor that they may be said to merely exist, rather than live, on the produce of their labour.

The alluvial gold is generally very fine, varying in weight from ·1 to ·005 grain, the largest flake found by the writer weighing no more than 2 grains. Much larger grains occasionally occur, for a nugget, having no quartz attached, was found at Sonapet in or about 1889, and weighed 18½ dwts.[1] In the sands of the large rivers the only gold recovered is as fine as flour, occurring in extremely thin flakes. The larger grains found in the gravels sometimes show a tendency to terminal crystallization, due to a secondary accretion of gold.

The quality of Jáshpúr alluvial gold is somewhat low. The first four following assays were made on Jáshpúr gold dust by Colonel W. A. Forbes, Mint Master, in 1847; the last three are of Sonapet gold dust, and were made by the present writer:—

No.	Gold.	Silver.	Base.
1	878·91	80·62	40·47
2	929·69	70·31	...
3	880·21	120·79	...
4	946·40	51·50	2·10
5	917·40	32 10	50·50
6	907·10	28·60	64·30
7	930·50	30·10	38·50

Nos. 1, 2 and 3 were gold dust. No. 4 was a nugget from Jáshpúr which originally weighed 221·87 grains, but which on cleaning was reduced to 199·6 grains. Its low specific gravity, *viz.*, 15·24, would indicate a considerable admixture of foreign matter, most probably quartz, a conclusion which is supported by an examination of the specimen, which is now in the Indian Museum, Calcutta, and which

[1] "Gold, etc., of Chota Nagpur," King and Pope, Calcutta, 1891, p. 78.

shows none of the rounded contours characteristic of true alluvial gold, but is wiry and hackly.

The alluvial area in the vicinity of Pharsabahal in Jáshpúr rests on a layer of granitic rocks, but its auriferous content is obviously derived from the rocks of the Dharwarian Series lying to the west.

It has been suggested [1] that the alluvial gold of the Íb River in the west of Chota Nagpur may have been derived from the rocks of Talchír and of Barákar age in the vicinity, which had been formed by the degradation of an auriferous area. Both were carefully examined in the locality cited, and many washings were made in streams flowing entirely over rocks of this age, all failing to give the faintest traces of gold. Moreover, an examination of the sandstones of Barákar age forces the conclusion that they were derived, not from a slaty or schistose area, such as is presented by rocks of the Dharwarian series, but rather from the degradation of the friable rock of a granitic area. The Talchírs in this area, being represented by carbonaceous shales, are extremely unlikely to furnish gold. It is therefore considered that the gold of the Íb River is derived, not from the Talchírs or Barákars, but from the Dharwarian rocks which are now known to exist within its basin.

Economic conditions.

It will no doubt readily be admitted that the search for gold is attended with the greatest possibilities of success when conducted on sound business principles. And since an examination of much of the work done on the Chota Nagpur gold occurrences during the "boom," reveals nothing so clearly as an absolute neglect of these fundamental principles, it will not be out of place to consider them briefly. While gold is by no means a rare mineral, and while there are few countries in which it does not occur, yet deposits of economic importance are far from numerous, and are scattered at wide intervals over the earth's surface. It therefore follows that not every deposit indicated by the presence of scattered gold grains will yield remunerative returns when found in its most concentrated state, or when traced to its parent vein. The first work, then, of the "prospector" is to find an area on which he is justified in spending a *limited amount of capital* in searching for payable veins or for alluvial "leads." This area is, in mining parlance, a "prospecting proposition." On it the prospector for auriferous veins

[1] "On the Diamonds, Gold, and Lead Ores of the Sambalpur District," Records, Geol. Surv., India, Vol. X, Pt. IV, 1877.

by washing in the streams and noting the relative richness of the "prospects," or by inspecting the outcrops of the veins, sets himself to discover the best positions for his trenches. These, before likely outcrops are discovered, are at right angles to the supposed strike of the veins, but after exposure of the veins are excavated along the outcrop to expose as great a length as possible. There is seldom occasion for the prospector to sink more than 10 or 15 feet: his work is essentially surface work, and he must from the outset be prepared to see his labour and his capital thrown away. But with the former properly directed and the latter judiciously expended, a very large area can be thoroughly prospected for a comparatively small sum, especially if the cardinal axiom of vein prospecting be borne in mind, *viz.*, that unless the vein shows gold on the surface and that in payable, or almost payable, quantities, it is useless and worse than useless to attempt to follow it down in the hope "of something turning up." Speaking advisedly, all the rich mines of the world are richest at the surface, and in no case has success resulted from sinking, in a new goldfield, on veins barren at the surface.

In the event, however, of the prospector discovering a vein payable at the surface, the outcrop must be opened up for as great a distance as possible and shallow shafts sunk on it at different points. If when all questions of labour, transport, fuel, water, etc., have been taken into account, the gold to be won appears to promise a reasonable interest on the capital to be invested (and this interest should certainly not be less than 12½ per cent.), then, and not till then, does it become a "mining proposition," in which work is concentrated at a point and for which a large capital is required. The distinction between a mining and a prospecting proposition is one that cannot be too clearly drawn, and is one that was never drawn during the Chota Nagpur "boom," if the works now in evidence and the over-capitalization of the companies formed be criteria.

With this brief preamble in mind, it may be stated that there is not exposed at the present moment, nor has there ever been exposed, in the whole of Chota Nagpur, a single gold-mining proposition, and further, there are but two or three doubtful prospecting propositions. The latter are, in order of apparent promise, (*a*) the high range between Manharpur, on the Bengal-Nagpur Railway, and Ankua, some six miles south-east of Manharpur Station, and (*b*) the country along the line connecting Sonapet with Sausal, and lying about three miles south of the diabase outcrop, with which it would appear that the deposition of gold is more or less intimately connected.

The Ankua range promises well for prospecting by reason of the coarse gold to be found in all the streams flowing from the range north-west towards the villages of Patarbasa and Gundria, and in the Sukha Nadi, flowing south-east from the same source, and further, by reason of the large veins in the vicinity. Some at least of the latter are auriferous, for a fragment from the cap of a reef was picked up in the Sukha Nadi, which showed very rich gold The presence of abundant iron oxides with the specimen would indicate its derivation from a reef containing much pyrites or galena—a conclusion in exact accordance with the already observed occurrences *in situ*. Of the second area nothing more favourable can be said than that it is the source of the gold of the Sona Nadi and of the Sanjai River, and, as we have already seen, the whole of the gold of these streams may have been furnished by thin and valueless veins similar to those of Sausal.

As has been above observed, while the capital required for prospecting should not be large in view of the remote chances of success, yet very thorough work can be done with limited capital. A properly constituted prospecting party should thoroughly and efficiently prospect many square miles of Chota Nagpur country for no greater sum than Rs. 7,500 to Rs. 10,000. It must, however, always be borne in mind that it is the height of folly to pay large sums to rajas and zemindars for mining rights, to erect expensive machinery and sink shafts, or to drive levels, unless good values are showing at the surface, and further, that in the case of Chota Nagpur reefs, special attention must be paid in prospecting to those carrying galena or pyrites, or having a gossan outcrop. In the former case assays should invariably be made.

The Chota Nagpur gold veins have often, by interested parties, been compared with those of the Kolar Field in illustration of the potentialities of the former. It has already been shown that the cases are not parallel. Moreover, and this is a point on which too much stress cannot be laid in view of the nature of the gold-quartz veins, there are no known extensive ancient workings such as led to the re-opening of the gold mines of Southern India, and yet sufficient evidence remains to show that it was not for lack of searching on the part of the natives that rich gold veins with consequent deep excavations were not discovered.

Turning now to the question of the recovery of gold from alluvial deposits, the outlook is not more hopeful. Generally speaking, "hydraulicking" as practised elsewhere is impossible owing to lack of water and poverty of gold content. At Sonapet, in the gorge above Bandidih, to the north, and in the gorge near Thorumba, to the west, conditions are extremely favourable for storage of hydraulicking water on a large scale and with a considerable head, but, as has been seen, the result of trials shows the average gold content of the Sonapet valley in this neighbourhood to be not more than 1½ to 2 grains per cubic yard, an amount far too low, considering the necessarily large capital, to give any hope of profitable return. At Ankua, also, water could be obtained by means of a race from the Junta Nadi to command the gravels, but the average gold content is here even lower than at Sonapet, being only about ½ to 1 grain per cubic yard. On the other side of the range, near the village of Patarbasa, the gravels are somewhat richer, but water for sluicing is absent.

Even with the low gold content of the gravels, it had been at one time the opinion of the writer that the gravels might profitably be shifted to suitable tail-races by coolie labour, but later experience showed that, however that may hold for dry gravel, the difficulties of cheaply shifting water-logged gravel, as most of that to be handled would be, are practically insuperable.

For testing the gravels, or for the recovery of gold on a small scale, the machine considered by the writer to be most suitable, and which, indeed, was used by him, is a modification of the West Australian dry shaker or "jigger," which can be operated with a little supervision by the least intelligent of coolies.

It has further been suggested, apparently by those ignorant of the nature of the Chota Nagpur rivers, or of the conditions requisite for successful dredging, that this form of gold recovery should be attempted. An inspection of these rivers affords convincing evidence of the impracticability of the suggestion for the following reasons, each one of which in itself being sufficient to defeat any such project :—

(*a*) The character of most of the river bottoms is absolutely prohibitive. The majority of the rivers flow over the upturned edges of hard, schistose rocks which would speedily destroy the dredge buckets if these were allowed to reach the bottom, where the richest deposits presumably lie. Unfortunately it is in these rocky bars that the gold is caught, and here it is that the native washer works with his iron hook in the narrow crevices into which the heavy sands have sunk. The long stretches of sand intervening between the rocky bars contain little or no gold. Further, the rock bottom is, as a rule, extremely uneven, often rising 20 feet with a perpendicular face.

(*b*) Owing to floods, dredging operations must be more or less intermittent. In a very good year, the dredgemaster could not hope for more than seven or eight months in which it would be possible to work full time. Moreover, with each flood, the paddock stripped to get at the bottom or at the auriferous stratum would be covered with fresh débris, perhaps 20 feet thick, and there is, with Indian floods, a probability of losing the dredge itself.

(*c*) The gold content of the gravels is insufficient. Leaving out of consideration the gold that may accumulate on the river bottom, and which is inaccessible for examination by ordinary means, the gold of the rivers is contained in the coarse gravels deposited in back eddies when the river is falling. These coarse gravels are of no extent, and are rarely more than 6 inches thick. Their auriferous content is seldom, even in the most favourable spots, more than 1 grain per cubic yard, so that the average content of the river sands must be practically *nil*.

"Pond-dredging" appears to be impracticable wherever the rocks of the Dharwarian series are at the surface. These rocks weather to form the ranges and ridges of Chota Nagpur, their resistance to rapid surface decomposition enabling them to offer an equal resistance to the levelling agencies of nature. There is therefore always present, even beneath the alluvial sands of a river valley, a hard, rocky, uneven bottom, absolutely inimical to successful dredging. Occasionally, however, as at Durjing, in the Bonai Native State, the alluvial sands are deposited on a granite bottom, which is often so decomposed that it can, with pick and shovel alone, be dug into for many feet from the surface. Such a bottom is naturally an ideal one for dredging, but, unfortunately, in the case cited, though the gravels were some 25 feet thick, and work could have been carried on all the year round, yet the gold content, averaging throughout the gravel less than ¼ grain per cubic yard, was so low as to preclude all possibility of success. Moreover, being situated some 25 miles from the nearest railway station, both fuel and material would be expensive from the difficulties of transport.

Finally, it must always be remembered that the foregoing observations are the result of a single season's work over a very wide area, and that the conclusions arrived at are therefore naturally liable to modification on the production of fresh data derived from a closer investigation. There may be, hidden away in the dense forest and covered up by the soil and by the vegetation of centuries, quartz veins rivalling in richness those of Southern India. Certainly it were the supreme height of folly to deny the possibility. But, with the data at hand, there can be only one conclusion, *viz.*, that, with two doubtful exceptions—and that only in the manner indicated—there is little scope for the legitimate investment of capital in the recovery of the gold of Chota Nagpur, whether from its sands or from its quartz veins. And further, whatever bonanzas the future may disclose for European exploitation, this at least is certain, that the greater portion of the auriferous deposits of that province must of necessity, from their poverty, be left to the native washer, forming for him a reserve that, though it will never raise him to affluence, will always lift him beyond the grasp of famine.

Appendix.

Subjoined are given the results of typical washings for alluvial gold, being selected from the tabulation of the numerous trials made during the course of the season's work. In all cases one cubic yard of gravel was selected for the trial, and unless otherwise specified, the results are to be considered as coming from the surface and from the spot likely to be most favourable in the vicinity for gold.

Locality.	Gold in grains per cubic yard.	Depth of deposit from the surface.	REMARKS.
Ankua . . .	2 1	Surface	From Sukha Nala.
" . . .	2·3	"	" " "
" . . .	2·8	"	" " "
" . . .	0 6	"	" " "
Gundria, 2½ miles S.-E. of Manharpur	2 8	"	Wash very limited
Durjing, Bonai . .	14	5-8 ft	}
Native State . .	·07	8-11 "	}
" " . .	·17	11-14 "	}
" " . .	·06	14-17 "	} Average, ·23 grain.
" " . .	·06	17-20 "	}
" " . .	·12	20-23 "	}
" " . .	1·00	23-24 "	} Bottom of hole.
Koel River near Manharpur.	·0	Surface	From gravels left in eddies
Brahmini River, near Durjing.	1·0	"	
" " .	4	"	
Burndabon, near Goilkera.	·68	"	
Burndabon, near Goilkera.	1 72	"	
" " .	4 86	"	Wash limited to a few cubic yards.
" " .	5 40	"	

Locality.	Gold in grains per cubic yard.	Depth of deposit from the surface.	REMARKS.
Sonapet . . .	1·2	7 ft.	
„ . . .	1·5	4-7 „	No. 7 pit.
„ . . .	·5	7-10 „	No. 7 pit.
„ . . .	1·4	8-11 „	No. 11 pit.
„ . . .	1·25	11-14 „	No. 11 pit.
„ . . .	2·15	14-17 „	No. 11 pit.
„ . . .	·95	6-9 „	No. 14 pit.
„ . . .	1·45	9-12 „	No. 14 pit.
„ . . .	2·5	12-15½ „	No. 14 pit.
„ . . .	1·44	15-16½ „	No. 14 pit.

ON THE FEASIBILITY OF INTRODUCING MODERN METHODS OF COKE-MAKING AT THE EAST INDIAN RAILWAY COLLIERIES, *by* T. H. WARD, A.M.I.C.E., F.G.S., *Officiating Superintendent, East Indian Railway Company's Collieries, Giridih.*[1]

In the course of my investigations I visited South Wales and Belgium (to see the Coppée ovens), and Sheffield and Middlesborough (to see the Simon-Carvés and Otto-Hilgenstock). I have had to content myself with the information given by Lunge in his work "Coal Tar and Ammonia," about the Otto-Hoffmann (the most successful oven in Germany), the Hussener and the Semet-Solvay, the two last-named being variations of Carvés.

In the older types of oven a mass of coal is ignited in a closed chamber, and a portion of the charge is burnt off in order to get up the right temperature at which the mass will cohere. The charge is then quenched, either in the oven (as in the Beehive), or after the withdrawal of the charge (as in the Anchor ovens). These latter ovens Dr. Saise introduced many years ago at Giridih. They are much larger than those in use in Wales, where the system was, at one time, so much in vogue, as it has been found that larger masses of Kurhurbaree coal coke best.

The modern system is to place the charge in a closed chamber, which is kept at the required high temperature entirely by the combustion of the gases given off. These are led through suitable passages and flues in the walls and floors of the closed chambers or ovens. There are almost numberless variations in the dimensions of the chambers and in the arrangement of the flues. In some of these, called "non-recovery" ovens, the gases evolved are used for the purposes of heating only—the major part being consumed in keeping up the heat of the ovens, and the surplus being utlized for steam generating or other purposes. In the "bye-product recovery" ovens, the gases evolved from the charge are passed through apparatus where they are deprived of tar and ammonia (and sometimes of benzol, though

[1] Dated 16th September 1902. Published by permission of the Agent, East Indian Railway.

this need not be considered here), and then passed on to heat the ovens, the surplus, after this primary object is attained, being utilized for steam generating and other purposes, as in the case of the "non-recovery" ovens.

It is important to note that the modern systems, whether "non-recovery" or "recovery," produce the maximum or theoretical yield of coke. That is, if a coal contain 24 per cent. of volatile constituents, the resulting weight of coke will be 76 per cent. The ash, too, can be accurately calculated beforehand. Suppose it is 12 per cent. in the coal in the above case, the coke will contain $\frac{12 \times 100}{76} = 16$ per cent. nearly.

With the old systems of coking such a coal as that instanced above would not yield more than 66 per cent. of coke, and this coke would contain about 19 per cent. of ash, a portion of the ash from the coal consumed for the heating of the oven being absorbed by the coke. These important advantages can, it should be carefully noted, be gained whether "non-recovery" or "recovery" ovens are adopted.

The "non-recovery" ovens are, of course, the cheaper form. In South Wales these are numerous, and are being gradually adopted throughout the district. The Coppée oven, which appears to me to do better as a "non recovery" oven, holds the field, the surplus gases being in all cases used to generate steam for winding, pumping, etc. The agent of Mons. Evence Coppée has kindly furnished me with an estimate of the number of ovens and the cost of materials required to manufacture our present output of, say, 20,000 tons of coke per annum. From this I roughly estimate as under:—

		£
Materials and plant in Europe		3,250
Fittings to be made in India		1,091
2,200 cubic yards brickwork at Rs. 6 per yard		880
Foreman—eight months at £40	£320	
Four masons—200 days at 64*s.* per day	650	1,203
Fares $\frac{5 \text{ by } 700}{15}$	233	
Labour		200
Freight		1,300
Cost in India of 28 ovens each 30 ft. by 6 ft. 6 in. by 2 ft.	£	7,924
	or £	283 per oven.

This is not a large expenditure for the manufacture of 20,000 tons of coke, and to secure the advantages mentioned above—

(1) Greater yield,
(2) Less ash,
(3) Generation of steam by surplus gases.

In addition to these advantages the cost of manipulating the plant, per ton of coke made will only be a fraction—it may be estimated roughly at one third—of the cost now being incurred. It should be here stated that the old prejudices against coke made by these modern processes (that it is less dense and of lower value for metallurgical purposes) have been entirely abandoned.

The reason for the extensive adoption of "non-recovery" ovens in South Wales is the fact that the coal does not contain a sufficient percentage of nitrogen to make the manufacture of sulphate of ammonia remunerative. In "Coal Tar and Ammonia," by Lunge (p. 704), Welsh coal is stated to contain ·91 per cent. of nitrogen and English coal 1·66 to 1·75 per cent. Our Kurhurbaree coal may belong to either of these categories. Moreover, it is important to note that the whole of the nitrogen in a coal is not available if the primary object of the process is the production of a good sound coke. As much as one-third of the total nitrogen is often left behind in the coke, the proportion depending on the form in which the nitrogen exists in the coal.

It is clear, then, that the first step in coming to a decision as to the adoption of "non-recovery" or "recovery" ovens is to have our coal tested. This can be done by Simon-Carvés, Otto-Hilgenstock or Coppée. A sample of about 100 lbs. in weight would be required by each. As the question is of such vital importance it would be quite as well to have three entirely independent opinions. The fee in each case will probably be £10, besides the cost of carriage of coal.

Another point will require investigation, *viz.*, whether a supply of sulphuric acid is available in Calcutta, and at what rate. The acid is required in large quantities (5 or 6 tons a week) for the manufacture of sulphate of ammonia, and we must ascertain that our demand will not greatly affect the market price. The present rate in England is 36*s.* per ton.

Supposing these preliminary difficulties are satisfactorily disposed of, there is no doubt that "recovery" ovens would prove highly remunerative, notwithstanding the considerable initial outlay. The improvement in the yield and quality of the coke which will result have been already referred to.

It may be as well to describe briefly the plant required. The products of distillation are taken into one or more gas mains with which each oven connects. These mains are connected with exhausters, the pressure being kept, in all the systems, as nearly as possible as that of the atmosphere. During the progress towards the exhausters a large part of the tar and all the pitch is condensed, and separated from the remaining gaseous products, which are then drawn through variously designed condensing and cooling apparatus where all traces of tar are got rid of. The remaining gas passes through the exhauster and is forced forward through scrubbers, where the ammonia is condensed and absorbed by water, forming ammoniacal liquor. In many cases the gases are further treated and the benzol recovered (this does not pay at the present time, and for the sake of simplicity I make no further reference to it). The gases are then carried back to the coke ovens to be burnt there for heating them, the surplus being available for other purposes.

The ammoniacal liquor is pumped into overhead reservoirs and is sent on to the sulphate of ammonia plant. Here the liquor falls from stage to stage in an apparatus where it meets with steam, the free ammonia being volatilized. The liquor is further treated with lime and the fixed ammonia freed. The ammonia is led into a vessel where it comes in contact with sulphuric acid and sulphate of ammonia is formed. The product runs in a continuous stream on to draining tables. After draining, the sulphate is bagged and shipped to all parts of the world.

There is a growing and practically an unlimited demand for sulphate of ammonia for agricultural purposes. It is displacing the nitrate of soda, which comes exclusively from Chili, and commands a better price, although it contains less nitrogen. There is a large consumption in Java, and we can sell any quantity in Calcutta for shipment. Messrs. Simon-Carvés offer to buy all our output. Their manager stated that he would be glad to purchase 20,000 tons at once.

The price realized for sulphate of ammonia is at present £11 5*s*. per ton. Lunge gives the following table of market prices per ton :—

	£	*s.*	*d.*
1896	7	18	0¾
1897	7	18	4½
1898	9	9	7½
1899	11	5	9¾

The rise in value shown has taken place and been maintained in spite of increasing production. Some consignments have been sold at £13 per ton (see note by Director, Geological Survey, below).

The General Manager of a very large concern (the information was given in confidence) stated that his sulphate of ammonia cost him, after allowing amply for depreciation, and all manufacturing charges, exactly £3 15*s*. to put on board, leaving a profit at present selling price of £7 10*s*. per ton. This gentleman was paying 36*s*. per ton for his sulphuric acid.

As we do not know what nitrogen our coal contains, it is impossible to make a calculation as to what our outturn of sulphate would be. We may, however, assume that, if our coal yields much less than 20 lbs. of sulphate of ammonia per ton, we should not put down "recovery" plant. Taking this as a basis and our output of coke at 20,000 tons per annum, from 30,000 tons of coal we should have about 270 tons of sulphate of ammonia to dispose of. The profit would be :—

270 tons sulphate of ammonia at £7 10*s*. per ton, say, £2,000.

The profits on tar would probably be much greater in India than in England, as all the tar and pitch used here is, I believe, imported from Europe. The cost of obtaining these bye-products is very small—say 2*s*. 6*d*. per ton, including all charges. Our coal would probably yield 70 or 80 lbs. of tar per ton, and we may with certainty reckon on 50 lbs. This would give us 700 tons per annum, or, at present English prices, £700 per annum.

The increased yield of coke would be 2,500 tons, and it would be of better quality, having some 3 per cent. less ash. I think the present issue rate for coke is Rs. 3-8 per ton, but even at this low rate the value of the increased yield would be £583 per annum.

The saving in labour charges would probably be not less than 8 annas per ton, or £750 per annum.

Collecting these items we have:—

	£
Profit on sulphate	2,000
Profit on tar	700
Increased yield of coke	583
Saving in labour charges	750
	4,033

Against which must be set the depreciation on, say, an outlay of £15,000 at 10 per cent., so that the nett profit would be £2,733, or no less than 18 per cent. on the total capital outlay, without taking any account of the improvement in the quality of the coke, or the value of the steaming power of the surplus gases.

The saving in labour charges is due to the use of mechanical appliances for loading and unloading, and to the fact that no night shift is required. In many places no work is done on Sundays, and it is never necessary except to get a larger output.

One of the most recent innovations and one which has resulted in a marked improvement in the density and appearance of the coke (in one instance an increased rate of 1*s.* 6*d.* per ton being readily obtained) is the compression of the coal charge by a stamp. The apparatus in the case of the Simon-Carvés ovens at Rotherham Main consists of:—

(1) A large hopper holding about 30 tons or 3 charges of damp coal from the washer.

(2) A steel trough, with one side and the bottom, or sole-plate, moveable, of the exact dimensions of the charge (8 feet by 20 inches by 33 feet).

(3) A quick-acting stamp.

(4) A winch engine for passing the charge into the oven and for traversing the whole apparatus.

(5) The usual "pusher-out" or ram, with engine complete, for extruding the coke.

The whole of this plant is mounted on the same frame, and can be traversed backwards and forwards along the whole length of the battery of ovens. As one of these compressors is sufficient to work 30 ovens, the cost is higher in proportion when the machine has to be applied to a smaller battery. The charge of coal having been watered and rammed, the side of the mould (trough) is slackened off, and the charge is passed into the oven on the sole-plate forming the bottom of the mould. This is a ¾ inch steel plate, on the bottom of which there is a rack engaging with a pinion of the winch engine. The charge having been placed in position in the oven, the door is secured so that the sole-plate can be withdrawn from underneath the charge. A charge can be rammed and placed in the oven in from 20 to 25 minutes. When a charge so treated is pushed out, the sight is a very remarkable one, as the coke does not usually fall to pieces. It stands on the "bench" a mass 6½ feet in height and 33 feet in length. In itself this shows that the compression has a marked effect. The coke was by far the best looking I saw anywhere, and it was stated that the specific gravity was 1·3 as compared with 1·15 without compression. About 15 per cent. more coal can be got into the same chamber by this system. The cost of the apparatus is about £3,000. As mentioned above, the relative cost is greater when a small battery is served.

It will be readily understood that such a process is better adapted to a large than to a small charge, and the tendency is now to increase the dimensions of the ovens. The plant at Rotherham Main, by the Simon-Carvés Company, is one of their latest, and the ovens there have been made 8 feet in height and 33 feet in length, while the other dimension has been kept the same 20 ins., so that the heat-radiating surface of the walls is increased in the same proportion as the mass of coal.

I am able to give the approximate cost of the Simon-Carvés and of the Coppée ovens ("recovery"). The Otto-Hilgenstock have not furnished me with any particulars of cost.

The cost of the Coppée "recovery" ovens I have estimated roughly from the particulars they give. Seventeen ovens would be required to deal with 600 tons of coal per week = 22,500 tons of coke per annum :—

	£
Materials and plant in Europe	9,500
Fittings to be made in India	1,400
2,500 cubic yards brickwork at Rs 6 per yard	880
Roofing exhauster house, sulphate of ammonia house, stove, etc.	500
Foreman, masons, etc., as in para. 7 (p. 93)	1,203
Labour	500
Freight	1,500
	£15,483
	= £910 per oven.

The cost of the Simon-Carvés plant has only been given to me in round figures. A 24-oven plant, including compressing plant, is given as £20,000. This plant would be capable of dealing with about 840 tons a week. To deal with 600 tons a week we should require only 18 ovens. As a compressor costs £3,000, it will be seen that each unit (oven) costs £350 and the tar-condensing and ammonia plant £6,000. The cost of 18 ovens would therefore be:—

	£
18 ovens, at £350 each	6,300
Tar-condensing and ammonia sulphate plant .	8,600
Freight	1,500
	£16,400
	=£911 per oven,

or practically the same as for the Coppée oven.

To this cost would have to be added the cost of the compressor, say, including freight, £3,300, or about £20,000, including compressing plant.

The plant would have to be erected at one of our mines where we can command a large supply of water in the hot weather. About 300 tons of water are in circulation in the condensing plant and about 3,000 gallons an hour will be lost. Some modification of the coolers would probably be advisable so as to utilize the evaporating power of the dry air during the greater part of the year, and this point should be borne in mind when the details of the apparatus are being arranged.

It will be noticed that the cost of "non-recovery" and "recovery" ovens per unit is 283 : 910 (taking the Coppée estimate, and excluding the cost of compressing), or about as 1 : 3. The total cost of the ovens in the two cases is, however, more nearly 1 : 1·9 as fewer ovens are required when the bye-products are recovered. This arises from the fact that in the latter case the process is under mechanical control (the exhausters), and a larger output per unit is got.

As regards the amount of surplus gas available, it is found that 10 ovens "non-recovery" will steam one full-sized Lancashire. In "recovery" ovens about the same result is got, provided the benzol is not removed, because more coal is burnt in the same time. About half the steam generated in the latter case is, however, required for actuating the plant. In the particular case considered above—the conversion of 30,000 tons of coal into coke per annum—the surplus gases would, in the case of the "non-recovery" plant, steam three full-sized Lancashire boilers, and in the case of the "recovery" plant only one (besides the boiler required to actuate the plant).

The conclusions in this note may be summed up as under:—

(*a*) That if the Kurhurbaree coal contains a sufficient quantity of nitrogen, and if a reasonably priced supply of sulphuric acid is available in Calcutta, it will certainly pay to put down bye-product plant to recover tar and ammonia.

(*b*) That if the nitrogen prove deficient or the supply of sulphuric acid high priced or deficient in quantity, "non-recovery" plant with utilisation of waste gases should be adopted.

(*c*) That in either case the improvement in the quality of the coke which results will justify the adoption of compressing plant.

Supplementary note by the Director, Geological Survey of India.

Coking in India is done at present in open kilns, no attempt being made to recover the bye-products, and it is only rarely, as in the case of the Anchor ovens, introduced by Dr. Saise at Giridih, that any attempt is made to utilize the full heating power of the waste gases. As a consequence, there is a great waste of coal, an undesirable increase of the ash percentage in the coke formed, and a loss of the valuable volatile constituents.

The limited demand of coke for metallurgical purposes is one reason for neglecting to produce a higher quality of coke in India, and the limited development of chemical industries accounts for the waste of the bye products.

At present about 300,000 tons only of Indian coal are converted annually into coke, though the demand will naturally increase with the development of metallurgical industries. Even as matters stand at present, Mr. T. H. Ward has shown that there is good ground for assuming that the additional outlay necessary for closed ovens, of the "recovery" as well as the "non-recovery" type would be repaid. Assuming that the coal used for coke-making in India contains on an average 0·75 per cent. of available nitrogen, the present system of manufacture in open ovens means an annual loss of 2,250 tons of nitrogen, sufficient that is for the manufacture of 10,613 tons of sulphate of ammonia, which, at £13 a ton, is worth £137,969, or more than 20½ lakhs of rupees.

Ammonium sulphate is the chief amongst the substances made from the volatile bye-products of coal, its principal value being, as a fertilizer, dependent on the nitrogen which forms 21·2 per cent. of the compound. It is thus superior to nitrate of soda, which contains 16·4 per cent. of nitrogen, but is not necessarily more valuable than the nitre so largely manufactured in India, as this contains, besides 14 per cent. of nitrogen, a proportion of potash which is also a fertilizer.

During recent years the manufacture of ammonium sulphate from the bye-products in coke-making has increased in the most remarkable way, with a coincident rise in price, which shows that the demand for such nitrogen-fertilizers has outpaced the supply, and the annual production in the world now exceeds half a million tons, sold at prices varying from £12 to £13 a ton.

In the note printed above, Mr. Ward has made out a good case for the introduction of "recovery" ovens, on the assumption that the Giridih coal will yield 20 lbs. of sulphate of ammonia per ton, and that with the price of sulphate at £11-5*s*. a ton, there would be a profit of £7-10*s*. Tests made at home show that Mr. Ward's estimate of the available nitrogen in the Giridih coal was a safe one (see assays below), while the market prices are now nearly £2 per ton above that which he took to be an average for sulphate of ammonia. The estimate of "profit" must depend on several factors, the most important being the cost of sulphuric acid, which will be materially reduced in India, if we succeed in utilizing our copper sulphide ores.

There appears to be no doubt about a market for the products. According to information obtained by the Agent, East Indian Railway, from the British Vice-Consul at Samarang in Java, the sulphate of ammonia imported to Java, mainly for the sugar plantations, amounted in 1901 to 21,700 tons and in 1902 to 23,400 tons, at prices varying from £14 to £15 a ton, of which about £1-10*s*. covered the freight from England. There is thus a certainty of a market in the Indian Ocean far beyond the probable output of sulphate of ammonia from India, and there would naturally be a large market in India itself for such a valuable fertilizer.

Through the courtesy of the Agent, East Indian Railway, I am permitted to publish the appended results of tests made by the Simon-Carvés Company on samples of coal sent from Giridih.

T. H. HOLLAND.

Assay of coal from the East Indian Railway Company—marked E. I. R. S/1—by Simon-Carvés Company.

			Dry coal.		Wet coal.		
Volatile matter.	Ammonia water.	Moisture . 0·00			1·77		
		Water of Condensation 1·70	1·70		1·67	3·44	
	Tar		6·00			5·89	
	Gas and loss . . .		14·20			13·95	
				21·90			23·28
Coke .	Fixed carbon . . .		62·97			61·86	
	Ash		15·13			14·86	
				78·10			76·72
				100·00			100·00

		Dry coal		Wet coal	
Gas (in volume) . .	per ton	9,944	c. ft.	9,764	c. ft.
Ammonia (by weight) .	„	6·9	lbs.	6,776	lbs.
Equivalent in sulphate of ammonia	„	26·8	„	26·325	lbs.
Benzole (at 150°) . . .	„	8·57	„ (=·95 gall.)	8·4	lbs. (=·935 gall.)
Ferrocyanide of sodium .	„	1·163	lbs.	1·142	lbs

Coke.—The coke is good without breeze; the assay in the crucible on the dry coal gave 76·21 per cent. of coke.

Assay of coal from the East Indian Railway Company—Marked E. I. R. K/1—by Simon-Carvés Company.

			Dry coal.		Wet coal.		
Volatile matter.	Ammonia water.	Moisture . 0·00			1·01		
		Water of Condensation 0·91	0·91		0·90	1·91	
	Tar		7·62			7·54	
	Gas and loss . . .		14·25			14·11	
				22·78			23·56
Coke .	Fixed carbon . . .		65·03			64·37	
	Ash		12·19			12·07	
				77·22			76·44
				100·00			100·00

		Dry coal		Wet coal	
Gas (in volume) . .	per ton	10,231	c. ft.	10,124	c. ft.
Ammonia (by weight) .	„	7,056	lbs.	6·98	lbs.
Equivalent in sulphate of ammonia	„	27·4	lbs.	27·1	lbs.
Benzole (at 150°) . . .	„	7·1	lbs. (=·8 gall.)	7	lbs. (=7 gall.)
Ferrocyanide of sodium .	„	·838	lbs.	·831	lbs.

Coke.—The coke is good without breeze; the assay in the crucible on the dry coal gave 74·60 per cent. of coke.

MISCELLANEOUS NOTES.

Fossil bones in the Godavari alluvium.

In February last Mr. H. F. G. Beale, of the Public Works Department, called my attention to the existence of fossil bones in the bed of the Godavari river at Nandur Madmeshwar in the Nasik district, Bombay Presidency. Mr. G. E. Pilgrim was at once deputed to excavate and identify the bones, amongst which he secured the cranium, part of the pelvis and the right femur of a remarkably large individual allied to, or identical with, *Elephas namadicus*, Falc. and Caut. A detailed description of the bones is now in course of preparation, and will be published in a later part of this volume. Near the bones of *E. namadicus*, Mr. Pilgrim found a portion of the lower jaw of *Hippopotamus* cf. *palæindicus*, some crocodile teeth and mollusca of recent species. The large bones were found in an old alluvial deposit of conglomerates and clays, excavated by the modern river and now forming cliffs rising to some 60 feet above the river bed. The alluvium is thus, like the older alluvium of the Narbada, probably as old as the pleistocene.

[T. H. HOLLAND.]

Fossils from the Yenangyoung Oil-Field, Burma.

Several fossils were sent by Mr. L. G. Boyde, which were found south of Singu in block N of the Yenangyoung oil-field. These include 16 distinct species of mollusca, all of them identical with species described by Dr. F. Noetling in "The Fauna of the Miocene Beds of Burma."[1] Of this 6 are placed by Dr. Noetling in the zone of *Mytilus nicobaricus*, occurring at Singu, while the remaining 10 are distributed throughout Dr. Noetling's other zones. These were all found *in situ* in beds of miocene age. Near the crest of the anticlinal, corals were found belonging to a species of *Dendrophyllia* allied to *D. digitalis*, Blainville.

Various mammalian bones and plates of *Garialis* were collected out of the débris in "chaungs" or ravines, but there is no evidence to show to what beds they belong. Amongst these is an interesting and well-preserved left upper molar tooth, which may be referred to the same genus, if not the same species, as the single specimen from the Punjab described by Mr. Lydekker as *Propalæomeryx sivalensis*.[2]

[1] Pal. Ind. New Series, Vol. I, pt. 3, p. 31.
[2] Pal. Ind. Ser. X, Vol. II, p. 173.

The following list is that of the Mollusca:—

Cytherea erycina, Lam.
Cytherea astricta, Reeve.
Cardita variegata, Noet.
Tellina grimesi, Noet.
Tellina protocandida, Noet.
Cardium minbuense, Noet.
Dione protophilippinarum, Noet.
Ostraea promensis, Noet.
Solarium nitens, Noet.
Turritella affiniformis, Noet.
Conus avaënsis, Noet.
Pyrula bucephela, Lam.
Pyrula pugilina, Born. spec.
Eburna protozeylanica, Noet.
Fusus seminudus, Noet.
Galeoda moniliformis, Noet.

[G. E. PILGRIM.]

Assays of Raniganj coals.

We are indebted to Dr. W. Saise, A.R.S.M., M.I.C.E., F.G.S., for the accompanying assays of coals from the Raniganj field. Dr. Saise calls attention to the remarkably constant differences in the percentages of moisture held by coals from the different geological horizons in the field. In the case of the Barakar stage, which is the lowest stage in the series, the moisture amounts to only 1 per cent., while in the lower seams of the Raniganj stage it averages 3·81, and in the upper seams 6·86 per cent. There is a parallel, but less pronounced, variation in the amount of volatile hydrocarbons: in coal from the Barakar stage the average is 26·57 per cent., in the lower seams of the Raniganj stage it is 31·70, and in the upper seams 32·22 per cent. It will be interesting to see if Dr. Saise's generalization with regard to the Raniganj area holds for other Gondwana fields.

[T. H. HOLLAND.]

Assays of coal from Raniganj coal-field.[1]

Name of mine and seam.	Moisture.	Ash.	Fixed Carbon.	Vol. Matter.	REMARKS.
RANIGANJ SERIES (UPPER SEAMS).					
Damudarpur	4·60	8·50	60·50	26·40	
Sunharpore	6·40	22·67	32·40	38·53	
Bonbahal	8·83	22·53	40·62	28·02	
Haripur	9·05	8·52	49·58	32·95	
Dobran	6·32	17·99	41·98	33·71	
Toposi	5·63	11·22	47·48	35·67	
Jameri	7·28	15·07	45·12	32·53	
Agerah	8·36	13·78	43·29	34·57	
Dobran	5·00	21·00	46·00	28·00	
Bonbahal	7·00	15·00	47·00	31·00	
Bajore	7·00	8·00	52·00	33·00	
RANIGANJ SERIES (LOWER SEAMS).					
Ghoosic	4·00	16·00	47·00	33·00	
Bhootdoba seams: 9 feet coal	4·00	19·00	46·00	31·00	
Ditto : 7 feet coal	4·75	19·00	45·50	30·75	
Sitalpur bottom seam, 9 feet	5·00	17·00	46·00	32·00	
Satukpur seams, 16 feet	3·5	18·00	49·00	29·50	
Do. top seam, 14 feet	4·75	15·00	47·00	33·25	
Damra coal, 12 feet	4·75	10·00	47·00	38·25	
Ghoosic coal, 14 feet	4·00	13·00	46·00	37·00	

[1] Assays by W. Saise, A.R.S.M., D. Sc., F.G.S., Superintendent, East Indian Railway Collieries, Giridih.

Name of mine and seam.	Moisture.	Ash.	Fixed Carbon.	Vol. Matter.	REMARKS.
RANIGANJ SERIES (LOWER SEAMS)—*concld.*					
Shibpore seam . . .	3·60	9·00	54·00	33·40	
Nundi seam . . .	6 20	13·50	47·50	32·80	
Baradhemo seam . .	2·50	18·00	47·00	32·50	8 feet seam.
Nundi	3·31	12·16	55·84	28 69	
New Baraboni . . .	4·00	9·00	61·00	28·00	
Adjai coal	2·75	11·00	55·00	31·25	
Jayramdanga . . .	...	11·00	56 50	33·00*	*Includes moisture.
Deshurgarh . . .	2·80	10·35	53·08	30·52	
Ditto . . .	1·50	13·00	51·00	34·50	
Jayramdanga . . .	4·11	9·42	56·47	29·99	
Nowparah, 15 feet seam .	4·00	10·50	58·50	27·00	
Belrooi	3·65	10·05	55·50	30·80	
Palasdih, 7 feet seam . .	3·00	19·25	46·25	31·50	
Dhadka seam . . .	5·13	8·84	56·14	29·89	
Borachak	5·00	14·00	50·00	31·00	
Kumarpore . . .	5·25	9·50	51·50	33·75	
Nowparah	3·15	27·50	...	29·85	Joyramdanga.
Panchgachia seam . .	3·40	15·00	...	30·40	
Joyramdanga . . .	2 25	13·00	53·50	31·15	
Bonbistupur . . .	2·50	13·00	51·00	23·50	
BARAKAR SERIES.					
Chanch	1·00	14·00	59·50	26·50	
Laikdih	1·25	14·00	61·00	23·75	

Name of mine and seam.	Moisture.	Ash.	Fixed Carbon.	Vol. Matter.	REMARKS.
			BARAKAR SERIES—*concld.*		
Sangamahul, 12 feet . .	1·50	16·00	55·00	27·50	
Chatabad, 12 feet . .	...	17·00	55·00	28·00*	Same as Sangamahul coal. *Includes moisture.
Sangamahul, 20 feet . .	0·50	25·00	49·00	25·50	*
Ditto, 8 feet . .	0·75	22·00	52·45	24·75	Bottom of lot.
Gaurangdih (average) . .	1·25	17·50	52·00	29·25	
Ditto (picked) . .	0·75	11·00	59·5	28·75	

Ancient kitchen-midden in the Andamans.

The question of the origin of the ancient kitchen-midden in the Andamans, referred to on a previous page (pt. I, p. 45) has been materially assisted by more recent observations by Mr. C. G. Rogers, Deputy Conservator of Forests, and by the identification of the two gold coins which were found. The inscriptions on the gold coins were first stated, on the authority of a local numismatist, to be illegible; but they were afterwards sent to the British Museum, where they have been identified by Mr. E. J. Rabson as coins of the Actien kingdom in North Sumatra. The inscriptions are in the Malayan variety of the Arabic character, and consist merely of the names and titles of two queens as follows :—

(1) Nūr-al-'Ālam, Nakayat-al-Dīn. (A. D. 1675—1677.)
Obv. فادك سري سلطان نور العالم
(Pāduka sri Sultān Nūr-al-'Alam).
Rev. نقيت الدين بر دوله شاه
(Nakāyat al Dīn bar Daulat Shāh).

(2) Kamālat Shāh, Zīnat-al-Din (A. D. 1677—1688.)
Obv. فادك سر[ي] سلطان كمالة شاه
(Pāduka Sr[ī] Sultān Kamālat Shāh).
Rev. زينة الدين بر دولة شاه
(Zīnat-al-Dīn bar Daulat Shāh).

Mr. C. G. Rogers has recently examined some undoubted Jorawa encampments on the south and middle islands, and has found in them pieces of pottery and iron weapons similar to those found in the supposed kitchen-midden at Cadellganj. There is no doubt, therefore, that the articles found at Cadellganj were accumulated in an old aboriginal settlement, probably occupied by the Jorawas, who are still wild and hostile in the central parts of the southern island. The coins, which are more than 200 years old, must have been imported either by traders or by a shipwrecked crew, and the other gold had presumably a similar origin. The occurrence of the metal in this locality thus does not in any way show the existence of native gold in the Andamans.

[T. H. HOLLAND.]

An instance of titaniferous iron-ore formerly smelted in native furnaces.

The iron-ores smelted in the native furnaces, according to the process which may still be seen in operation at the present day and has been described by various observers during the nineteenth century, are generally of the friable ochreous kinds. Many instances are quoted in the Records and Memoirs of the Geological Survey in which furnaces erected in the immediate neighbourhood of rich beds of massive hæmatite and magnetite are fed with nodules laboriously gathered over a vast extent of land, either from the lateritic soil, or amongst sandstone beds of Gondwana age. That a better class of ores has been worked in former times is made evident by the existence of ancient mines, such as those situated in the Dhar Forest and elsewhere, excavated through compact siliceous hæmatites and magnetites which would be refractory to the present native method of treatment. An interesting instance of this sort was brought to notice by Mr. Holland during a recent visit to Kishengarh in Rajputana, the ore being a highly ferriferous ilmenite. The mineral occurs abundantly in large well-shaped crystals associated with quartz and largely crystalline clear calcite in a broad vein which traverses granitoid gneiss, and is situated one mile east by a little north of Kanchria, a village three miles south of Kishengarh. There are remains of excavations made at an unknown period, in which a few cupriferous stains forming thin films on some of the vein minerals lend apparent support to a tradition according to which these excavations represent an abandoned copper mine. Heaps of slag occur in the immediate neighbourhood. Chemical analysis shows that the slag is undoubtedly an iron one, and the presence in it of a small amount of copper and a large proportion of titanium clearly indicates its connection with the mineral of the neighbouring vein. In spite of its refractory nature, the titaniferous iron-ore must have been smelted, no doubt on account of the high class of the metal obtained. The copper is present in the slag only as an impurity, and appears to occur in very small amount as a constituent of the mineral vein. The large and well-shaped crystals of titaniferous iron-ore form aggregates in which individual crystals measure two or three inches in diameter. Their specific gravity is 4·60. They are strongly magnetic. They are steel-gray, with a sub-metallic lustre. The streak is brownish. Qualitative chemical tests reveal the presence of ferric iron in great abundance, with a considerable, though smaller, amount of the ferrous oxide. Titanium is abundant. Magnesia, manganese, nickel and copper are absent. There is a trace of lime. Specimens of the crystals are exhibited in the mineral collection of the Museum, with the register number J. 368.

[E. VREDENBURG.]

Discovery of Thenardite at Didwana, Rajputana.

Two more species must be added to the list of minerals known to occur in India.

Thenardite has been collected by Mr. A. F. Ashton, Officiating Commissioner, Northern India Salt Revenue, in the salt pans of the Didwana Source, situated about 35 miles from the Sambhar lake in a north-westerly direction, and described by C. A. Hackett in Volume XIII, of these Records page 201.

The salt is practically pure anhydrous sulphate of soda. It contains no chlorine, no lime, and only a minute trace of magnesia. The crystals are wedge-shaped, and consist principally of the unit pyramid.

[E. VREDENBURG.]

Discovery of Cancrinite in Kishengarh.

Another felspathoid has been found near Kishengarh amongst the remarkable group of intrusive rocks that have already yielded such exceptional examples of this class of minerals.

The specimens were collected by Babu Baidyanath Saha, M.A., who sent me the fragments for determination. The mineral is described by Baidyanath Saha as forming veins in which it is associated with biotite.

It occurs at the base of a small hill north of Mandaoria, a village situated three miles north-north-east of Kishengarh. The locality thus defined is in the direct continuation of the strike of the elæolite-pegmatites containing the extraordinary sodalite described in Part 1 of this volume (page 43). During my short stay at Kishengarh, I did not go north of Mandaoria. South of the village, I observed the elæolite-syenites forming the lower spurs on the western side of a tall ridge largely composed of scapolite-diorites striking, north by east, immediately to the east of Mandaoria. These scapolite-diorites appear to be intimately connected with the elæolite-bearing rocks.

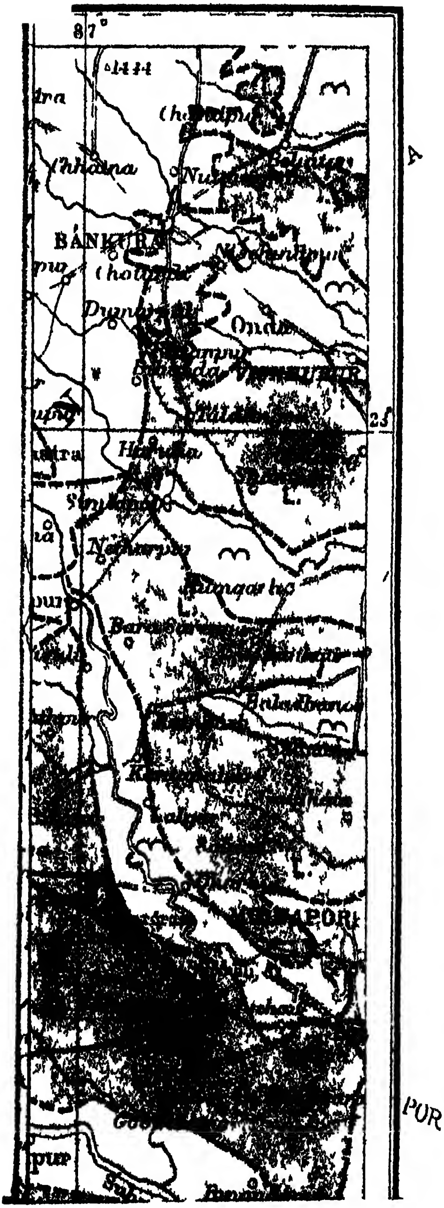
Baidyanath Saha has traced the continuation of the elæolite-syenites up to the cancrinite veins north of Mandaoria, where they probably still occupy the same position relatively to the scapolite rocks at the northern end of the ridge, as was observed by me in its southern part.

The cancrinite specimens received in the laboratory are white and translucent. The specific gravity is 2·47. The vertical cleavage is highly developed. The fracture at right angles to the cleavage is irregular and subconchoidal. The specimens consist almost entirely of cancrinite in large interlocking completely allotriomorphic crystals. The only other mineral visible is biolite forming local aggregates of very minute grains.

Thin sections cut at right angles to the cleavage clearly show the uniaxial interference figure. The mineral is very fusible. It is completely decomposed by hydrochloric acid with effervescence, and gelatinisation of the silica after heating.

[E. VREDENBURG]

G. I. C. P. O.,—No. 199 D. G. Survey—24-6-04—J. Marum.



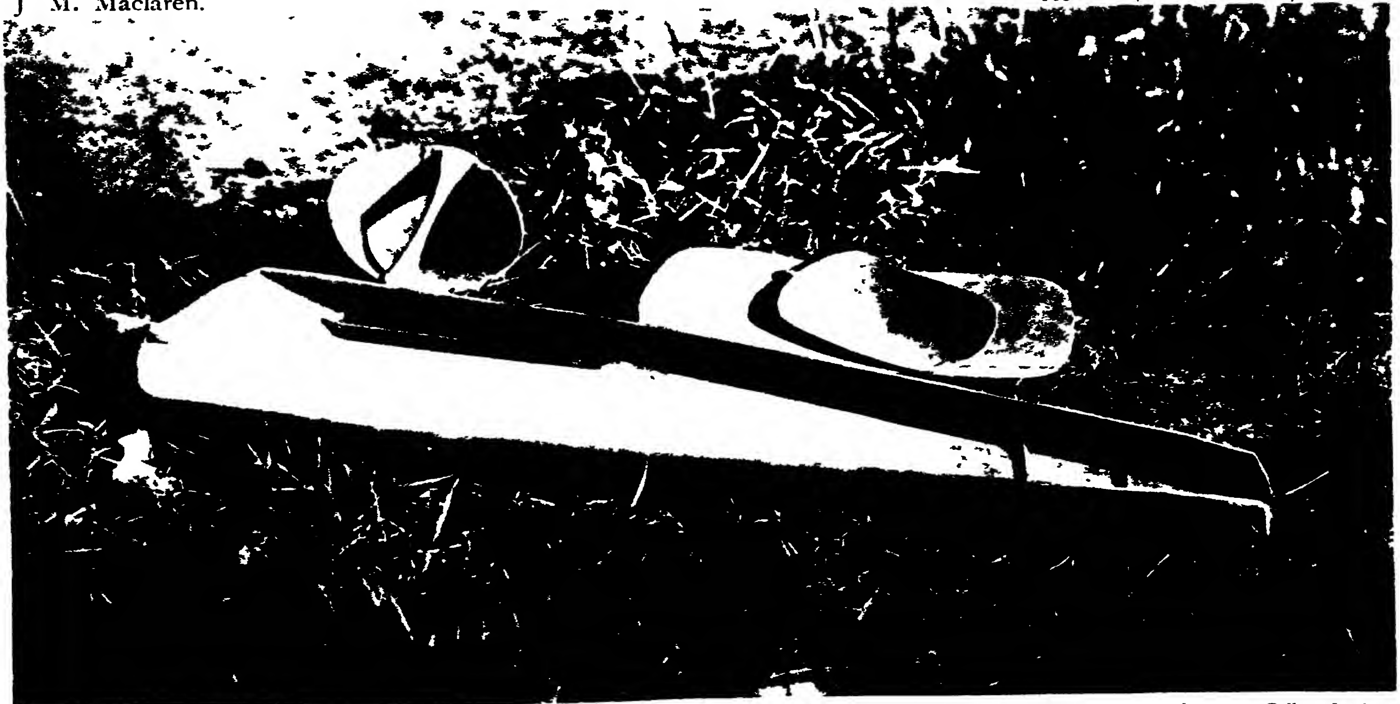
INDEX

- *Alluvium*
- L — *Laterite*
- *Deccan Trap*
- *Lameta*
- B — *Barakar*
- T — *Talchir*
- Kar — *Kurnul*
- Cud — *Cuddapah*
- Dh — *Dharwarian*

IGNEOUS

- *Diabase*
- Gn — *Gneisses & Granites*
- *Intrusive Granite*

J. M. Maclaren. Records, Vol. XXXI, Pl. 7



J. M. Maclaren Photo. Bemrose, Collo., Derby.

GOLD-WASHING TROUGH ("DHUIN"), WATER VESSEL ("KARI" AND SMALL WASHING TROUGHS. PHARSABAHAL, JASHPUR.

J. M. Maclaren. Records Vol. XXXI, Pl. 8.

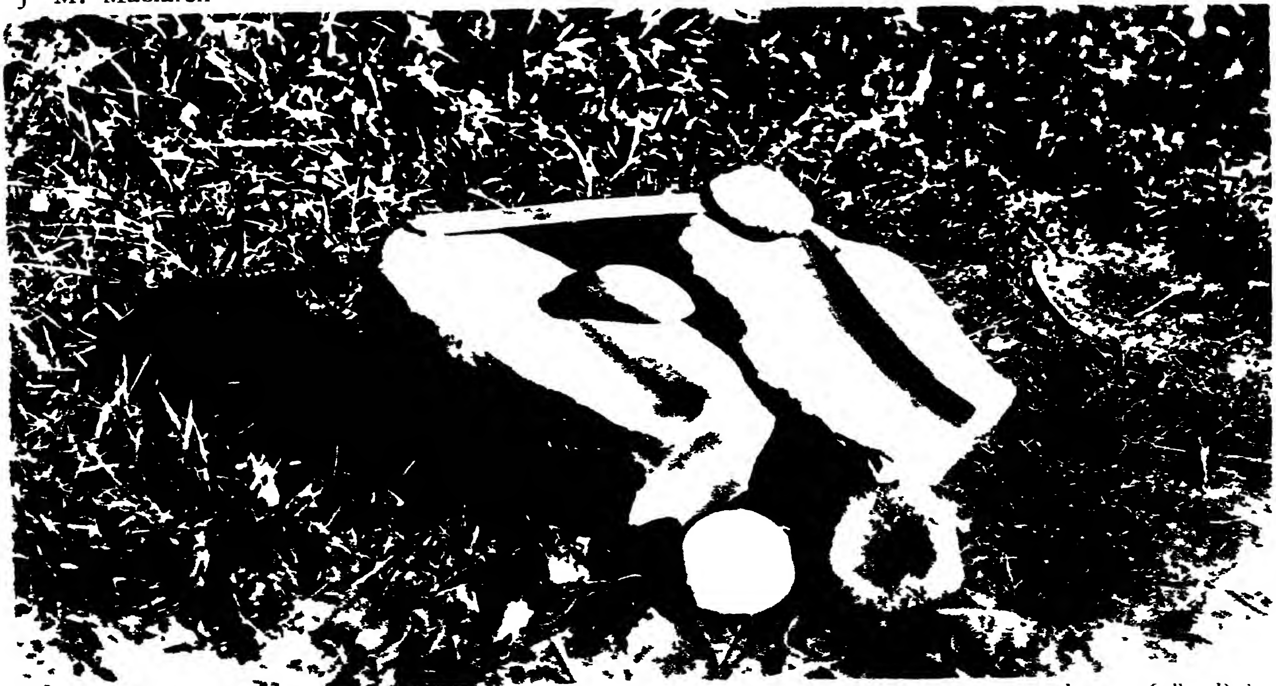
J. M. Maclaren, Photo.

GOLD WASHING "JIGGER" USED FOR TESTING GRAVELS

CHOTA NAGPUR

J. M. Maclaren

Records, Vol. XXXI, Pl. 9



J. M. Maclaren Photo

Hemrose Collo. De by

ANCIENT CRUSHING MILLS. KATIAR, SINGBHUM.

J. M. Maclaren.

Records, Vol. XXXI, Pl. 10

J. M. Maclaren. Photo.

Fig. 1.

Fig. 2.

Bemrose. Collo., Derby.

Fig. 3.

NATIVE GOLD-WASHER TH PATTA AND KORNE PORAHAT, CHOTA NAGPUR.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1904. [July.

THE UPPER PALÆOZOIC FORMATIONS OF EURASIA. *By* TH. TSCHERNYSCHEW, *Director of the Russian Geological Committee.*[1] *Translated by* PROFESSOR P. BRÜHL, *Civil Engineering College, Sibpur.*

We commence our summary of the Upper Palæozoic formations with the eastern slope of the Ural. The most comprehensive information about the nature of the Carboniferous sediments of this region we owe to A. Karpinsky, who has published not only a geological map of the Asiatic side of the said mountain range, but also a series of preliminary reports on the scientific results of his many excursions into the Ural Mountains. On the basis of these published data, and of the additional information extracted from the yet unpublished complete geological description of the eastern flanks of the Ural Mountains and kindly supplied to me by the above-mentioned scientist, we are able to draw up the following scheme of the structural features of the respective Carboniferous sediments.

The base of the Carboniferous sediments is formed by shales, argillaceous slates, sandstones, and conglomerates, which enclose beds of coal and concretions of clay-ironstone, and which, at their lower horizons pass insensibly into sandstones and slates of Devonian age. Organic remains are almost exclusively represented by plants, *Lepidodendron Glinkanum*, Eichw., *Stigmaria ficoides*, Brongn., etc.

[1] Forming pages 709—733, 740—742 of a monograph entitled "The Upper Carboniferous Brachiopods of the Ural and Timan Mountains," Mem. du Comité Géologique, vol. XVI, No. 2. St. Petersburgh, 1902.

The strata just referred to are overlaid by limestones with valves of *Productus giganteus*, Mart., and *Pr. striatus*, Fisch., and prominent coral banks. Here and there these undoubted Lower Carboniferous limestones are covered by others, which differ considerably from them palæontologically, and which in all probability belong to the middle division of the Carboniferous system. The same age is probably correctly ascribed to the palæontologically well-characterized Goniatite beds of Schartymka.

In most cases these limestones are overlaid by calcareous shales and calcareous sandstones, which enclose valves of *Spirifer mosquensis*, Fisch., in association with forms (gastropods and brachiopods) which remind one forcibly of corresponding forms from the middle division of the Carboniferous strata of the Donez basin. The uppermost beds of the Carboniferous system, as developed on the eastern slopes of the Ural Mountains, consist of white or yellow tripoli-like rocks, of marls, sandstones, clays, and gypsum, which very distinctly mark the boundaries of the Carboniferous sea-basin just before its complete disappearance.

As pointed out by A. Karpinsky,[1] an interesting complication in the architectonic features of the Carboniferous sediments may be observed at the eastern side of the Ural Mountains. The limestones of Lower Carboniferous age (with *Productus giganteus*) are succeeded immediately by rather thick conglomerates and breccias, which enclose frequently fragments of the underlying limestone with *Productus giganteus*, but which in other localities are of a more varied composition, without the former limestones losing their preponderance. Fragments of one decimeter in diameter to the size of a human head, sometimes even from 0·6 to 1 meter across, are frequent. The interstices between the larger pieces are filled with smaller fragments, and the whole is cemented together by a compact argillaceous calcareous matrix, which reminds one of a hardened calcareous mud. According to the statement of A. Karpinsky, the fragments are either rounded or entirely angular. In most cases not a trace of stratification is observable in the matrix of these conglomerates and breccias, provided one does not mistake the cracks traversing the blocks of rock for such Above the conglomerates are found sandstones, marls, and argillaceous limestones, which here and there contain thick accumulations of masses

[1] Bull. Com. Géol., T. VIII, S. 204—206; Guide des exc. du VII. Congr. Géol. Intern., V, p. 12,

of corals (according to A. Stuckenberg's determination *Chætetes radians*, Fisch., *Syringopora parallela*, Fisch.). Although these conglomerates, as mentioned above, are not developed in all localities, and may be even wanting, in consequence of which there rest, immediately on the lower and partly on the middle limestones, rocks which in other places overlie the conglomerates, their mere existence, and the occurrence of numerous fragments with *Productus giganteus*, point to the fact that during the Middle Carboniferous epoch continental conditions obtained on the eastern flanks of the Ural Mountains, if not generally, at least locally. The origin of the conglomerates, possibly glacial like those of the Talchir group or the corresponding formations in Australia, is a question which for the present must remain in abeyance.

After a second visit to the banks of the Bagarjak, where the most instructive exposures of the conglomerate are found between the villages of Osmanowa and Kosakowa, A. Karpinsky expresses himself rather cautiously, but he is inclined to acknowledge the glacial origin of the conglomerate. Although the boulders show no instances of polishing and striation which could not be ascribed to tectonic changes (dislocations or faulting on a smaller scale), the absence of stratification, of signs of a sorting of the constituents, and the probable contemporaneity of their formation with Carboniferous glacial deposits of other countries speak nevertheless, according to the views of that scientist, rather for a glacial origin of the conglomerates.

East of the Ural Mountains we meet with two extensive spreads of Carboniferous deposits, in the Kirgise Steppes and in the basin of Kusnezk. According to the latest results of the geologists who took part in the surveys carried out along the Siberian railway, as well as of the scientists who shared in the labours of the geological section of the Cabinet of His Imperial Majesty the Emperor of Russia, the composition of the Carboniferous sediments of the Kirgise Steppes resembles that of the basin of Kusnezk very closely. In both cases there occur, at their base, limestones with a Lower Carboniferous marine fauna, which in its essential features is very similar in the two areas, but which differs considerably[1] from the contemporaneous fauna found on the eastern slopes of the Ural Mountains.

[1] *Syringothyris cuspidata*, Mart., and *Spirifer tornacensis*, de Kon., which are characteristic of the deposits in the Kirgise Steppes and the basin of Kusnezk, are total strangers to the fauna of the eastern slopes of the Ural Mountains. *Productus giganteus*, Mart., which is common here, is nearly entirely absent from the Lower Carboniferous deposits of the Kirgise-Steppes and the Altai.

All those observers who have been working in both the areas referred to have invariably come to the conclusion that there is no break between the above-mentioned limestones and the overlying productive series, and they adduce a number of facts which bear testimony to the gradual displacement of the marine Lower Carboniferous sediments by argillaceous and arenaceous deposits interstratified with beds of coal.

But with regard to the age of the productive deposits, or rather in the determination of the chronological limits within which they have to be disposed, opinions differ considerably. This divergence of opinion exists chiefly with reference to the basin of Kusnezk, since with respect to the age of the coal-beds of the Kirgise-Steppes A. Krasnopolsky, N. Wyssozky and A. Meister have, after the detailed investigations carried out between 1894 and 1896, arrived unanimously at the conviction that it is impossible to see in the coal-bearing series sediments younger than Carboniferous. With reference, however, to the basin of Kusnezk, most geologists who have had the opportunity of acquiring an intimate acquaintance with the coal-bearing strata of that region ascribe to them an age not more recent than Carboniferous. But of the palæophytologists who have studied the flora buried in these strata, some (Geinitz and Grand-Eury) consider it to be an equivalent of the productive series of Western Europe, others (Schmalhausen, Kosmowsky) ascribe to it a Mesozoic (Jurassic) age or place it within the limits formed by the Permian and Jurassic systems. The most detailed analysis of the available information concerning the age of the flora of the coal-bearing strata of Kusnezk is due to Zeiller,[1] who, after having studied the papers of Schmalhausen,[2] has arrived at some important results. Of interest to us among these results is the demonstration of the peculiar features of the flora of Kusnezk, which, like the one discovered by Bodenbender and Kurtz in Argentina, is a mixture of European forms with representatives of the Glossopteris-flora of India. According to Zeiller, this peculiar feature can be explained only on the hypothesis that the basin of Kusnezk, similarly to the Argentinian provinces of

[1] R. Zeiller, Remarques sur la flore fossile d'Altai. Bull. Soc. Géol. de France, 3. Sér., T. XXIV., p. 446—487.

[2] J. Schmalhausen, Beiträge zur Jura-Flora Russlands. Mém. Ac. Imp. des Sc. de St. Pétersbourg. 7 Sér., T. XXVII, No. 4 (1879). J. Schmalhausen, Die Jura-Flora des Basins von Kusnezk und des Petschora-Landes. Verhandl. d. Kais. Min. Ges., 2 Serie, T. XVI (1881)—S. 97—178 (russ.).

San Luis and La Rioja as well as the province of Rio Grande do Sul in Brazil,[1] constituted an intermediate region between two distinct botanical provinces. In his paper Zeiller also touches upon the age of the strata of Oranez on the Petschora, from where Schmalhausen has described the *Rhipidopsis ginkgoides*, which Kurtz has discovered also in Argentina, and Schmalhausen declares that species to be of Permian age, which approximately harmonizes with the fact well-known to Russian geologists that the beds of Oranez belong to the Artinskian stage. Similarly does the previously mentioned author ascribe a Permian age to the flora of the coal-bearing series of the Kusnezk basin, although he does not consider its identity with the flora of the Petschora, which is assumed by Schmalhausen, to be proved. On the whole Zeiller proceeds with great caution, and is of opinion that a final solution of the problem is quite possible, provided not only that the collection of fossils is continued, but that the detailed stratigraphical study of the coal-bearing strata is not neglected. This author has already been able to make use of an interesting find, which has been made by P. Wenjukow[2] in the shales which accompany the coal-beds of Koltschugin and which consists of some species of pelecypods and ostracods, of which W. Amalizky has determined *Posidonomya Becheri*, Brown, and *Carbonicola carbonaria*, Goldf. No less remarkable are the discoveries made by I. Tolmatschew on the river Tersja, among which Jones[3] has distinguished six pelecypods (*Anthracomya minima*, Ludw., *A. lævis*, Dawson, var., *A. valencinnensis*, Eth., *Posidonomya subovata*, n. sp., *P. concinna*, n. sp.) and a representative of the ostracods (*Beyrichia Kirbyana*, n. sp.). Jones does not doubt the Carboniferous age of this fauna, and even questions the propriety of ascribing it to the *upper* division of the productive series. These finds lead us back to our original view concerning the age of the coal-bearing beds of the basin of Kusnezk, and on the basis of numerous observations made by the geologists who have been working in that area, they force us to consider the continental deposits

[1] Compare M. R. Zeiller, Note sur la flore fossile des gisements houillers de Rio Grande do Sul. Bull. Soc. Géol. de France, 3 Sér, T. XXIII, p 601—629.

[2] P. Wenjukow, Geol. Unters. in der nördl. Partie d. Bas. v. Kusnezk im Sommer, 1894. Travaux de la Sect. Géol. du Cab. de Sa Maj, T. I, liv. 2, p. 86.

[3] R. Jones, On some carbonif. shale from Siberia. Geol. Mag., Dec. IV, vol. VIII, p. 433—436.

of that region as forming an uninterrupted series, whose development had, in all probability, been carried to an end before the deposition of the Artinskian strata of the Ural (inclusive of those of Oranez, on the Petschora). If we apply these data to the profile of the Gondwana series of India, it appears most probable that the coal-bearing sediments of the basin of Kusnezk correspond in general to the Lower Gondwanas (to the Talchirs and Karharbaris), and the Artinskian stage with the lower stage of the Damuda series (the Barākars), whilst the sediments on the Dwina, in which W. Amalizky has discovered a Glossopteris flora in association with a rich vertebrate fauna, may be considered as homotaxial with the upper stage of the Middle Gondwana beds (the sandstones and red clays of the Panchets). Such a comparison gives the conglomerates on the eastern slopes of the Ural Mountains described above a special interest; for if we ascribe to them a glacial origin, the period during which they were being laid down almost corresponds to that of the deposition of the Talchir boulder bed, the glacial origin of which admits of no doubt.

Returning to the consideration of the marine equivalents of the Carboniferous deposits of the Ural and the Timan Mountains, we must not forget the fact that, with the exception of the Ussuri country, no such deposits are known to occur throughout the wide expanse of Siberia. To the interesting limestones discovered by Dr. A. v. Bunge and Baron E. v. Toll in the outermost portion of the Lena-delta, no age less than Middle Carboniferous can be ascribed, to judge from the fauna buried in those limestones.[1]

South of the Ural Mountains, in the regions of the Ural and the Turgai and in the territory between the Ural and the Caspian Seas, no Upper Carboniferous deposits are known.

To judge from the palæontological collections which have been gathered by A. Romanowsky and J. Muschketow as well as a

[1] E. v. Toll, Géol Skizze der Neusibirischen Inseln. Mém. de l'Acad. Imp. des Sc., T. IX, No. 1 (1899), p. 8. This fact has evidently been overlooked by Frech when working out his map on the distribution of land and sea during the middle carboniferous epoch (the epoch of *Spirifer mosquensis*); for the outlines of the eastern arctic continent must be subjected to considerable corrections in view of the occurrence of middle carboniferous marine deposits along the lower course of the Lena (compare Fliegel, Die Verbreitung des marinen Obercarbon in Süd-und Ost-Asien. Ztschr. d. Deutschen Geol. Ges. Jahrg 1898, S. 385—410, Frech, Lethæa geogn., II, Lfg. 2, Karte 3).

number of other investigators,[1] a complete series of deposits with *Spirifer mosquensis* and of overlying beds corresponding to the Upper Carboniferous strata of Eastern Russia are developed in Turkestan, as well as beds which are analogous to the Artinskian sediments of the Ural region, and among them beds with cephalopods which are perfectly identical with those of the Ural. As correctly noticed by A. Karpinsky,[2] the existence of similar deposits in Darwâs, which in a straight line is at a distance of 1,800 kilometers from the Ural, is very remarkable and brings out the importance of this province and of the surrounding mountainous districts, which are only at a distance of 650 kilometers from the Salt Range, for the study of the relations between the Upper Palæozoic strata of Russia and those of India. However scanty the data may be which E. Suess[3] has been able to gather from the materials collected by Stoliczka and K. Bogdanowitsch, partly on the Pámirs and the southern spurs of the Thian-Shan, partly in the western parts of the Küen-Lün Mountains, they point to the fact that the profile of the Upper Carboniferous strata of these mountainous regions belongs to the same type as the Uralo-Timanian deposits, and the data obtained by v. Loczy[4] and W. Obrutschew in Eastern Turkestan, in Nan-Shan and in China point on the whole in the same direction.[5]

Whilst there exist among geologists no differences of opinion of any importance with regard to the chronology of the Upper Palæozoic strata of Central Asia and China, we meet in the profiles of the Salt Range and the Himalaya with deposits the bathological position of which among the whole series of the Upper Palæozoic formations cannot be regarded as finally determined.

[1] The results of the study of these collections are found in G. Romanowsky, Materialien z. Geol. v. Turkestan, Lfg. 1—3, 1880—1890.

[2] A. Karpinsky, Ein Hinweis auf d. Vork. v. permo-carb. Schichten in Darwaz. Verh d. Russ. K. Min. Ges. 2. Ser. Bd. XVIII, S. 219. Mat. z. Geol. Turk., Lfg. 2, S. 141.

[3] E. Suess, Beitr. z. Strat. Central Asiens. Denskchr. d. Math. Nat Cl. d. Kais. Ak. d. Wiss. Wien. 1894.

[4] V. Loczy, Wiss. Ergebnisse d. Reise des Grafen Széchenyi in Ostasien. III. Bd., IV. Alth, 1898.

[5] Preliminary data obtained from the material gathered by him have been communicated to me by Obrutschew and have been incorporated in his published account of his travels. (Central Asien, Nord-China und Nan-Shan. Published by the K. Russ. Geogr. Ges.)

I consider it first of all necessary to take up the Salt Range in somewhat greater detail, because its stratigraphy has been investigated more fully than that of any other district in Asia with respect to the sequence of geological horizons as well as their palæontological contents. I consider it all the less superfluous to state my views on that profile, as the latter serves as a standard profile in discussions on the age not only of Asiatic, but also of Australian Palæozoic formations.

In the concluding volume of the work devoted to the description of the above-mentioned Indian deposits, Waagen,[1] on the basis of the investigations of Wynne and Warth as well as of his own observations, gives the following classification of the Palæozoic formations of the Salt Range, commencing from above :—

Topmost beds of the Upper Productus Limestone .	= Chidru beds.
Cephalopoda beds „ . „ „ „ .	= Jabi beds.
Lower and middle divisions „ „ „ .	= Khund Ghat beds
Upper division of Middle Productus Limestone .	= Kalabagh beds.
Middle „ „ „ „ .	= Virgal beds.
Lower „ „ „ „ .	= Katta beds.
Lower Productus Limestone or Upper Speckled Sandstone	= Amb beds.
Middle Speckled Sandstone.	
Lower „ „	= Boulder beds.

Of the subdivisions only the Middle Speckled Sandstone is unfossiliferous, and it is therefore not characterized palæontologically. The other horizons are all more or less rich in fossils. The latest discoveries in this respect have been made in the Lower Speckled Sandstone, from which two faunas have been obtained, one rich in *Conulariæ* and the other with peculiar *Conchiferæ* (*Eurydesma*). Both faunas are very similar to that buried in the lower productive deposits of New South Wales and the corresponding ones of Tasmania. Quite apart from the agreement in the palæontological contents of the Australian and Indian sediments, Waagen draws our attention to the interesting fact that in the very same series of Australian deposits glacial boulders similar to those of the Indian boulder beds, especially those of the Salt Range, have been found.

With respect to the age of the various subdivisions of the Productus limestone, Waagen's views underwent considerable changes between

[1] Waagen, Salt-Range Fossils, Vol. IV., Geol. Results, p. 241.

the years 1872 and 1895. At first[1] he was inclined to consider the whole series of Productus limestones to be of Carboniferous age. In the year 1879 he commenced the publication of his classical treatise on the fauna derived from the Productus limestone, and this afforded him an opportunity of giving expression to his essentially altered views on the age of the several members of the Productus limestone series, before the whole of the various monographs on the subject in question had yet appeared in print;[2] he ascribes a Carboniferous age only to the lower Productus limestones, whilst he refers the corresponding middle and upper limestones to the Permian system. Three years after the publication of the last part of the monograph on the fauna of the Productus limestone, Waagen fixed the age of the lowest subdivision to lie at the boundary between the Carboniferous and Permian periods, and in 1891, when he summarised the conclusions which he had drawn from the geological results of the study of the fauna in question, Waagen drew a parallel between the beds of Amb and Katta and the Artinskian deposits and the Limestone-Dolomite horizon of the Ural; further between the Virgal and in part also the Kalabagh beds and the Zechstein of Kostroma, whilst he sees in the whole of the remaining suite of the Productus limestone an equivalent of the rest of the Permian deposits of Russia.

One need not be astonished at the change in the views of a scientist of the first rank; for up to the present it is only in two countries (Russia and North America) that the whole series of the Upper Palæozoic formations is known from typically marine deposits; and as long as the fauna of these sediments, especially those of Russia, had not received a sufficiently exhaustive treatment, there did not exist any palæontological standards of comparison for the determination of the relative age of strata, standards which could have been applied to such a complex of horizons as presented by the Productus limestone, the Upper Palæozoic strata of the Himalaya, the corresponding formations of Australia, etc. Consequently opinions on

[1] Waagen, Mem. Geol. Surv. of India, Vol. IX, Pt. 2 (1872), p. 353. It will not be amiss here to point out that it was Russia where the first correction of this view on the age of the Productus limestone originated, and that it was A. Karpinsky who, without being in possession of palæontological data with respect to the various sub-divisions of that series of limestones, gave a very definite expression of the view that among the strata of the Salt Range here referred to there are equivalents of the Russian Artinskian sediments.

[2] Waagen, Z. d. D. G. G. 1834, S. 881.

the subject could not be based on a comparison with strata, the age of which was undoubted, so that the only available guiding principles were general considerations of a biological character. I have, however, pointed out before how reliable the foundations are which are furnished by such characters, and I intend to refer to them again in the sequel.

At the time when the first part of my treatise was already in the hands of the printer, there appeared a comprehensive contribution to the geology of the Salt Range from the pen of Noetling.[1] This scientist denied the existence of Carboniferous deposits in the Salt Range, and considered the boulder beds as well as the overlying *Eurydesma* and *Conularia* sandstones and the Warcha-beds as homotoxial with the Rothliegende, whilst all the subdivisions of the Productus limestone, according to his opinion, belong to the Thuringian stage of the Zechstein Noetling, in his treatise, lays repeated stress on the impossibility of drawing a dividing line based on lithological character between the upper beds of the Thuringian stage and the lowermost horizons of the Trias, and points out that in the Salt Range the replacement of the Neodyas or Upper Permian sea by the sea of the Trias has been perfectly gradual. Without entering here on an analysis of the chronological correlation adopted by Noetling, a task which I will defer, I consider it appropriate to remark that he adduces scarcely any fresh palæontological facts which would form a complement to Waagen's work, and that his deductions rest essentially on the forms described by the last-named author. This is why I do not see any sufficient reasons to abandon the scheme proposed by Waagen in his monographs, when comparing the Brachiopod fauna described by myself with that of the Productus limestone of the Salt Range; and as a matter of fact I consider it of little importance whether we carry out our synchronisation according to Waagen's scheme or according to the zones proposed by Noetling.

From the tables in which our knowledge of the distribution of the Brachiopods from the Timan and Ural Mountains according to horizons and sub-horizons is summarized, it is seen that the following Timano-Uralian forms are represented in the Salt Range :—*Dielasma elongatum*, Schloth.; *D. truncatum*, Waag.; *D. itaitubense*, Derby.; *Hemiptychina sublaevis*, Waag.; *Nothotyris*

[1] Noetling, Neues Jahrb. f M., Beil. Bd., XIV, 1901.

nucleolus, Kut ; *N. simplex*, Waag.; *N. Warthi*, Waag.; *Camarophoria superstes*, Vern.; *C. globulina*, Phill.; *Athyris pectinifera*, Sow.; *A. Royssiana*, Keys. = *A. acutimarginalis*, Waag.; *Hustedia remota*, Eichw. = *H. grandicosta*, Waag.; *H indica*, Waag ; *Spiriferina ornata*, Waag.; *Sp. cristata*, Schloth.; *Sp. Panderi*, Moell. = *Sp. nasuta*, Waag.; *Spirifer striatus*, Mart.; *Sp. fasciger*, Keys.; *Sp. Marcoui*, Waag.; *Martinia semiplana*, Waag.; *Reticularia elegantula*, Waag.; *Streptorhynchus pelargonatus*, Schloth.; *Derbyia regularis*, Waag., *D. grandis*, Waag.; *Rhipidomella Pecosi*, Marcou; *Chonetes morahensis*, Waag., *Ch. trapezoidalis*, Waag.; *Aulosteges dalhousii*, Dav.; *Productus Humboldti*, d'Orb.; *Pr. Cora*, d'Orb.; *Pr. lineatus*, Waag.; *Marginifera typica*, Waag.; var. *septentrionalis*, mihi.

This list can be extended, if we add the forms which replace closely related forms from the Ural :—

Salt Range.	Ural and Timan
Dielasma breviplicatum, Waag.	*Dielasma dubium*, mihi.
„ *problematicum*, Waag.	„ *timanicum*, mihi.
Terebratuloidea Davidsoni, Waag.	*Terebratuloidea triplicata*, Kut
Camarophoria Purdoni, Dav.	*Camarophoria mutabilis*, mihi
„ *humbletonensis*, Howse	„ *applanata*, mihi
Spirifer alatus, Schloth.	*Spirifer Dieneri*, mihi.
Martinia elongata, Waag.	*Martinia applanata*, mihi.
Streptorhynchus pectiniformis, Dav.	*Streptorhynchus Halli*, Derby.
Schizophoria juniceps, Waag.	*Schizophoria juresanensis*, mihi.
Chonetes strophomenoides, Waag.	*Chonetes Moelleri*, mihi.
Productus spiralis, Waag.	*Productus uralicus*, mihi.
„ *ovatus*, Waag.	„ *transversalis*, mihi.
„ *Purdoni*, Dav.	„ *irginæ*, Stuck.

If we add these forms to the list of the forms which are common to the Ural and Timan mountains and to the Salt Range, the total reaches 44, of which 16 have been found in the lower, 33 in the middle and 19 in the upper Productus limestone.

If we institute a still more detailed comparison, we discover that of the 16 forms which are common to the lower Productus limestone (the Amb beds) and the Uralo-Timanian Carboniferous strata, 5 forms belong to the *Omphalotrochus* horizon, and among them *Spirifer Marcoui*, Waag., which up to the present seems to be confined to this horizon ; another 8 forms are from the Cora horizon ; and among them *Productus Cora*, d'Orb., which is only rarely met with in the middle Productus limestone, predominates as well in Eastern Russia as in the Salt Range; finally 15 forms found in the lower Productus limestone have also been discovered in the Schwagerina horizon of the Ural mountains; but almost all of them (13) belong to the species which are either rare in this horizon within the Salt Range, or which pass into the overlying middle Productus limestone.

Continuing our investigation into the middle Productus limestone, we soon notice that in the lower section, the Katta beds the latter have 15 forms in common with the corresponding sediments of Russia, in which 3 forms have been found in the Omphalotrochus horizon, 3 in the Cora horizon, and 12 in the Schwagerina horizon, and among the latter particularly so common a form as *Notothyris nucleolus*, Kut., as well as *Hustedia indica*, Waag., *Streptorhynchus pelargonatus*, Schloth., *Derbyia grandis*, Waag., and *Streptorhynchus Halli*, Derby, which are no less common in the Schwagerina horizon of the Ural and the Timan. Still more striking is the resemblance between the middle section of the middle Productus limestone (the Virgal beds) and the Schwagerina limestones of the Ural and the Timan mountains: among the 22 species which are common to the corresponding horizons of the Salt Range and the Ural and Timan there is not one which cannot be found in the Schwagerina horizon, notwithstanding their comprising such characteristic forms as *Camarophoria superstes*, Vern., *Hustedia remota*, Eichw., *Spiriferina Panderi*, Moell., *Spirifer fasciger*, Keys. (very rare in the lower strata of the Salt Range), *Martinia semiplana*, Waag., *Derbyia regularis*, Waag., *Derbyia grandis*, Waag., *Chonetes morahensis*, Waag., *Terebratuloidea triplicata*, Kut., *Camarophoria mutabilis*, Mihi, *Streptorhynchus Halli*, Derby, and *Marginifera typica*, Waagen. Not without significance is the fact that both in the Schwagerina horizon of the Ural and in the Virgal beds representatives of the family of the *Lyttoniidæ* make their appearance, which mark a very characteristic and definite moment in the history of the Upper Palæozoic strata of Russia.

In the upper section of the middle Productus limestone, the Kālabāgh beds, the palæontological agreement with the Schwagerina horizon is considerably less noticeable, there being no more than 11 common forms. Slightly greater is the number of species common to the Schwagerina horizon and the lower section of the upper Productus limestone (the Khund Ghat beds), and nearly the same thing holds good with respect to the Cephalopod beds of the Upper

Productus limestone (Jabi beds), which enclose 13 forms occurring also in the Schwagerina limestones of the Ural and the Timan.

Hence a comparison of the brachiopod fauna of the Upper Carboniferous sediments of the Ural and the Timan Mountains with that of the various subdivisions of the Productus limestone of the Salt Range makes it pretty clear *that the lower Productus limestones—the Amb beds—are most correctly co-ordinated with the Spirifer Marcoui and Omphalotrochus Whitneyi horizon of the Ural and the Timan, and that we may see in the Russian Schwagerina horizon the most natural equivalent of the larger part of the middle Productus limestone, whilst the Cora horizon is to be considered as homotaxial with the upper Amb beds and probably also with the lower horizons of the middle Productus limestones or the Virgal group (of Noetling).*

In this correlation the Kālabāgh beds and the upper Productus limestone find (at least as a whole) their counterpart in the Artinskian sediments of the Ural mountains and their equivalents on the Timan.

This result is in considerable disagreement with the predominant views on the age of the various subdivisions of the Productus limestone of the Salt Range, and virtually leads us back to the original conception that they are of Carboniferous age I quite foresee that against my deductions the objection will be raised that they are based solely on a comparison of the brachiopods; but I can support them by the results of an investigation into other classes of the animal kingdom. I have something particular to say on the Cephalopods, especially the Ammonites.

The monograph of A. Karpinsky on the ammonites of the Artinskian sediments has established the important facts that the representatives of this fauna cannot be considered as immigrants into the Ural area, but that they must be regarded as autochthonous and that the Sicilian ammonite fauna described by Gemmellaro, apart from some Arcestidæ, possesses an Artinskian facies. A Sicilian form, *Medlicottia Trautscholdi*, is, according to Karpinsky, identical with the Uralian *M. Orbignyana*; two others, *Gastrioceras sosiense* and *Agathiceras Suessi*, are closely related to *G. Suessi* and *Ag. uralicum* respectively from the Artinskian sediments, in addition to which 8 species described by Gemellaro remind one forcibly of Uralian ones. "The most essential deviation of the Sicilian fauna," says

Karpinsky, "appears to lie in the appearance of the complex Arcestidæ (*Cyclolobus* or *Waagenoceras* and *Hyattoceras*), which are unknown in the Uralian area. Furthermore, many genera which are common to Sicily and the Ural mountains are represented in the former country by more complex forms. All this points to the Sicilian fauna being of a somewhat later origin than that of the Ural, notwithstanding its being closely related to the Artinskian fauna. On the other hand it is possible that the difference referred to is due to local causes.

The more complex Arcestidæ may for instance belong to a more southern area. That the latter explanation, in itself quite natural, is possibly correct, has not been recognised by the majority of the scientists who have dealt with the Artinskian sediments, and in conformity with Waagen's mode of procedure it became customary to assign to the Sicilian Fusulina limestones a position considerably higher than Artinskian. Co-ordinating the latter with the Katta and Amb beds, Waagen considers the Fusulina limestone of Sicily as homotaxial with Virgal and Kālabāgh beds, and he places the Cephalopod beds of the Salt Range or the Jabi beds still higher, in line with the Upper Permian deposits of Russia In my opinion such a co-ordination was hardly intended by A. Karpinsky, when he spoke of the possibility of the *somewhat* later origin of the Sicilian fauna with respect to the Artinskian sediments. With respect to the cephalopod beds of the Salt Range, A. Karpinsky, in conformity with the data obtained by me from a study of the Artinskian brachiopods, considers them as later than Artinskian, and in placing the latter in line with the middle Productus limestone, he assigns to the former a stratigraphical position below the upper Productus limestone of the Panjāb.

These conclusions followed quite naturally from the palæontological data then available. At present, however, when the Upper Carboniferous brachiopod fauna of the Ural and the Timan has been worked out, and when the deductions based thereon point with sufficient clearness to the homotaxial equivalence of the Upper Carboniferous division in Northern and Eastern Russia with the Amb, Katta, and Virgal beds in the Salt Range, a correction of the older conceptions becomes unavoidable. I have especially to observe that since the publication of the treatise of A. Karpinsky and of my own work, there has been gathered from the Artinskian deposits of the Ural an extensive supplementary material, and among it cephalopods, which promise, as soon as worked out in detail, to contribute essentially towards the solution of the problem concerning the correlation of the Upper Palæozoic strata of Russia with those of India.[1]

Quite recently some facts have been discovered with respect to the Salt Range which are not without interest in connection with the subject at present under discussion; for it is now settled that the cephalopods are not restricted to the Jabi and Chideru beds, but are also met with in strata corresponding to the Kālabāgh beds, and according to Noetling numerous specimens of *Xenodiscus carbonarius*, Waag., have been found in the former. Similarly Diener has worked out the limestone fauna of Chitichun in the Himalaya, and he co-ordinates it with the upper section of the middle Productus limestone of the Salt Range (the Virgal and Kālabāgh beds) as well as with the Artinsk horizon of Eastern Russia. Among the members of this fauna Diener describes a *Popanoceras* (*Stacheoceras*) *Trimurti*, Diener, which possesses its nearest analogue in the Sicilian Fusulina limestones of corresponding age. F. Noetling maintains on the basis of the most recent collections of Walker, that two faunas are found in the section of Chitichun, an older one with *Productus semireticulatus* and a younger one, which either characterises the complete suite of the Productus limestones or at least its middle and upper subdivisions (the Virgal and Chideru beds in Noetling's sense). In connection with the subject dealt with by us the possibility of such a division is not a matter of great moment; for it involves only the recognition of the fact that the profile of Chitichun contains, besides Artinskian strata, also equivalents of the Schwagerina horizon of Russia. We are confirmed in this view by a comparison of the brachiopod fauna from the already mentioned Russian deposits with the fauna worked out by Diener, which demonstrates the occurrence in the Chitichun profile of forms which hitherto had been exclusively or mainly confined to the Schwagerina limestones of Russia (*Productus simensis*, mihi = *Pr. Cora*, Diener, *Productus transversalis*, mihi = *Pr. semireticulatus*, Diener, *Marginifera typica*, Waag., *Spirifer tibetanus*, Dien., *Camarophoria mutabilis*, mihi = *C.* aff. *crumena*, Dien., *Notothyris nuclecolus*, Kut.

[1] I draw, for instance, attention to the fact that I have found in the palæontologically well characterized Artinskian sediments of the Northern Geese Cape on Nowaya Semlya remains of a *Medlicottia* which reminds one strongly of *Medlicottia Wynnei*, Waagen, possessing a similarly complicated suture-line.

which reminds one vividly of *N. subvesicularis*, Dav.) as well as of species which are exceedingly common in the Artinskian deposits (*Productus cancriniformis*, mihi, *Productus mongolicus*, Diener, *Spirifer fasciger*, Keys., *Sp. Wynnei*, Waag., *Martinia semiplana*, Waag.). Whilst therefore I consider it highly probable that part of the profile of Chitichun has to be placed side by side with the uppermost horizons of the Carboniferous system, I have to declare myself in agreement with Diener when considering the beds with *Popanoceras Trimurti* as homotaxial with the Russian Artinskian stage; and we receive consequently a further testimony in favour of the correlation of the Virgal beds or the middle section of the middle Productus limestone with the Schwagerina horizon of Russia, and of the Kālabāgh beds together with part of the upper Productus limestone with the Russian Artinskian sediments.

Very important is also the discovery of remains of *Helicoprion*, Karpinsky, in the upper Productus limestone of Chideru. Although Koken suspects that we have here to deal with a species different from *H. Bessonovi*, Karp., from the Artinskian deposits of the Ural Mountains, there can be no doubt that the period of existence of such a specialized animal type must have been restricted. In the Ural Mountains all localities of *Helicoprion* lie within the Artinskian horizon. But the horizontal distribution of that genus is rather wide; for at the present moment we have representatives of the genus, which possibly are identical with *H. Bessonovi* and in any case are closely related to it, from North America, Japan, India, and Australia.

In favour of the indicated correlation, and in any case in contradiction of the view that the whole series of the Productus limestone is to be assigned to the Permian system are the results of a comparison of the pelecypod fauna. Although this class of mollusca remains to be described as far as the Upper Carboniferous deposits of Russia are concerned, the available data justify me in referring to some interesting facts concerning them. Within the Upper Carboniferous deposits of the Ural and the Timan Mountains pelecypoda are most plentiful in the Cora and Schwagerina horizons. In the Salt Range the lower Productus limestone is relatively poor in representatives of this class.[1] Somewhat richer is the middle division, from which Waagen has described 10 species—7 from the

[1] According to Waagen only 4 species have been found in the lower Productus limestone.

Virgal and 5 from the Kálabágh beds.[1] The largest number of pelecypods has been reported from the upper Productus limestone; 18 species occur in the beds of Khund Ghat, 10 in the cephalopod beds of Jabi, whilst finally the beds of Chideru enclose the richest and most varied fauna, consisting of 31 species.

In the Omphalotrochus and Cora horizons we meet only three forms which show a great likeness to Indian forms: *Aviculopecten elegantulus*, Stuck., which in many respects reminds one of *A. derajatensis*, Waag., from the Virgal beds, *Pseudomonotis pseudoradialis*, mihi, closely related to *Ps. radialis*, Phill., and still more closely to *Ps. radialis*, Waag., and *Lima retifera*, Shum., which according to Waagen is very similar to *L. Footei*, Waag., also obtained from the Chideru beds. An incomparably larger number of forms, which agree with Indian ones, are met with among the pelecypods of the Schwagerina horizon, where, apart from *Aviculopecten elegantulus*, Stuck., which reminds one of *A. derajatensis*, Waag., *Macrodon semilarvis*, Keys, is very common, which is distinguished from *M. geminum*, Waag., from the Virgal and Kálabágh beds solely by its somewhat finer ribs. Besides these, there have been found in the same horizon in the Ural mountains *Myophoria praecox*, Waag. (Chideru beds), *Pecten prototextorius*, Waag. (Khund Ghat and Jabi beds) and *Lithodomus simplicissimus*, mihi, which is possibly identical with, and in any case closely related to, *L. atavus*, Waag. If we add that in the Schwagerina limestones there has been discovered a very conspicuous *Pseudomonotis*, which is not distinguishable from *Ps. gigantea*,[2] Waag., we cannot deny the resemblance of the Upper Carboniferous pelecypod fauna of the Ural mountains to that obtained from the middle and upper Productus limestone of the Salt Range. In no case are the data derived from a study of the pelecypod fauna contradictory to the deductions concerning the homotaxiality of the Schwagerina limestones of Russia with the Virgal beds and partly also with the Katta beds of the Salt Range, and in any case they must be considered as supplying a stronger proof than is furnished by the discovery, in the Virgal beds of *Pseudomonotis garforthensis*, King, the only lamellibranch which according to Waagen's opinion proves the Permian age of these deposits.

[1] In the Katta beds not a single specimen of a pelecypod has been discovered.

[2] The position of this species in the Productus limestones is not known with certainty, but Waagen believes it to have been obtained below the middle Productus limestones.

To confirm his views on the age of the Virgal beds, Waagen draws attention to a group of five forms which stamp the fauna of those beds as comparatively young; but, as we have seen above, it is not otherwise with the fauna of the Schwagerina horizon of Russia. Doubtless we shall be able to pass from the sphere of more or less probable conjecture to the region of well-ascertained facts only when the pelecypod fauna of the Artinskian deposits are as completely known as is the case with the brachiopods. Nevertheless, the rich material gathered within the past years entitles us to maintain that the resemblance of the pelecypod fauna, already well marked in the case of the Schwagerina horizon on one hand and the Productus limestones on the other, must be still more striking in the case of the Artinskian deposits. On the contrary, in the typical Permian sediments of Russia, very complete information on the fauna of which we owe to the monograph of A. Netschajew, we find in a purely marine facies close upon 100 different representatives of the genera and subgenera *Ostrea*, *Prospondylus*, *Lima*, *Pecten*, *Aviculopecten*, *Pseudomonotis*, *Liebea*, *Bakewellia*, *Modiola*, (*Lithodomus*), *Modiolopsis*, *Modiolodon*, *Macrodon*, *Nucula*, *Leda*, *Dolabra* (?), *Schizodus*, *Solemya*, *Pleurophorus*, *Astarte*, *Cardiomorpha*, *Edmondia*, *Solenopsis*, *Crassiconcha* and *Alorisma*, and among all these only one is in common with the middle and two with the upper Productus limestone. To ascribe such a great difference solely to the peculiarities of the Permian sea of Russia is hardly justifiable, the less so as a great number of the enumerated genera and subgenera from the Permian deposits of Russia are also found in the Productus limestone of India.

The corallian and bryozoan fauna too of the Productus limestone and of the Uralo-Timanian Upper Carboniferous deposits are capable of furnishing some materials for proofs. Both are restricted to the middle and upper divisions of the Productus limestones.[1]

The total of the Bryozoa described by Waagen and Pichi does not exceed 18, of which only four are met with in the middle division of the Productus limestone. A comparison of the forms worked out by the above-mentioned palæontologists with those from the Upper Carboniferous of Russia and studied by A. Stuckenberg teaches the following facts: *Fenestella perelegans*, Meek, from the middle Productus limestone, is very close to *F. elegantissima*, Eichw., from the

[1] In the lower Productus limestone occur two corals (*Orbipora ambiensis* and *Stenopora hemisphaerica*) and two Bryozoa (*Polypora vermicularis* and *Thamniscus serialis*).

Schwagerina horizon; *F. jabiensis*, W. et P. (middle and upper Prod. limestone), is hardly distinguishable from *F. foraminosa* (Schwag. hor.); *Polypora megastoma*, de Kon. (middle Prod. limestone), has been found in the Upper Carboniferous limestone of the Ural; *P. ornata*, W. et P. (middle and upper Prod. limestone), is compared by the authors with *P. orbicribrata*, Keys., *P. subquadrata*, Toula, and *P. cyclopora*, Eichw., forms which have been obtained from the Schwagerina horizon; *P. sykesi*, deKon. (middle Prod. limestone), approaches *P. papillata*, M'Coy (Schwag. hor.); *P. biarmica*, Keys. (upper Prod. limestone), is identical with the species bearing the same name from the Schwagerina horizon; *Phyllopora cribellum*, W. et P., is near *Ph. micropora*, Stuck. (Cora hor.); *Synocladia virgulacea*, Phill. (middle and upper Prod. limestone), is very closely related to *S. arboracea*, Stuck. (Schwagerina hor.); similarly, *Goniocladia Indica*, W. et P. (middle Prod. limestone), and *G. concatenata*, Eichw. (Schwag. hor.); *Thamniscus serialis*, W. et P. (lower and middle Prod. limestone), reminds one vividly of *T. timanicus*, Stuck. (Schwag. hor.); and finally *Acanthocladia anceps*, Schloth. (middle Prod. limestone) bears more resemblance to *A. carbonica* (Schwag. hor.) than to the Permian representatives of Schlotheim's species. Consequently, of the total number of the Bryozoa of the Productus limestone, eleven forms are either identical with representatives of the Timano-Uralian fauna or at least remind one forcibly of them. Of these one belongs to the middle Productus limestone and ten to the Schwagerina horizon of the Ural and Timan mountains. The resemblance with the upper Productus limestone extends only to five forms of the Schwagerina horizon, and with the lower Productus limestone only to one. From this it appears clearly that an examination of the Bryozoan fauna leads to the same result, namely, the agreement of the fauna of the Schwagerina limestone of Russia with that of the middle Productus limestone.

A lesser number of points of contact are furnished by the Corallian fauna, which is scantily represented in the Productus limestones and which receives a peculiar character from the predominance of types which resemble Lower Palæozoic ones. Notwithstanding this, a considerable resemblance with the Russian Upper Carboniferous fauna is unmistakable.

Michelinia Abichi, W. et W. (upper Prod. limestone), is very near *M. tenuisepta*, Phill. (Schwag. hor.); *M. placenta*, W. et W. (upper Prod. limestone), resembles, according to Waagen and Wenzel, *M. favosa* (Schwag. hor.) rather strongly; *Geinitzella columnaris*, Schloth.

(middle and upper Prod. limestone), is common in the Cora and Schwagerina horizons; *G. crassa*, Lonsd. (middle? and upper Prod. limestone), has also been found in the Schwagerina horizon; *Amplexus Abichi*, W. et W. (upper Prod. limestone), is scarcely distinguishable from *A. coralloides* (Schwag. hor.); *Dybowskiella grandis*, W et W., is very near *D. labiata* (Cora? and Schwag. hor.).

According to my own opinion all that has been said is directly in contradiction to the conclusions of Waagen and his followers, who see in the series of Productus limestones the counterpart of the Permian deposits of Russia; and the Productus limestones have to occupy, in the general chronological scheme, a position lower than that assigned to them by Waagen, Noetling, and other geologists.

There is only one fact of a geological character which does not harmonise with this lower position and that is the gradual petrographical transition, insisted upon by Noetling, from the uppermost horizon of the upper Productus limestone to the lower Triassic beds (the Scythian stage) According to Noetling's statement, which is based on the sections of Chideru and Virgal, the repetition of the same rocks within a succession of rocks which belong to the upper Productus limestone and to the Lower Trias furnishes a powerful argument in favour of the close relation between the Triassic and Permian sediments of the Salt Range, and the whole question with respect to the discordant or transgressive stratification appears to him pointless under the circumstances. The thorough palæontological disagreement between the strata of Chideru and those of the Scythian stage, which are separated from the former by only a few yards, is explained by Noetling on the supposition that the end of the Permian period and the beginning of Triassic times were characterised in the Salt Range by a frequent change in the lithological facies, which could not but influence the organic life very markedly. In this change Noetling finds the best explanation of the sudden extinction of the brachiopods. But this explanation is hardly applicable to the fact pointed out by Waagen that, as far as his information went, *not a single form can be traced from the Chideru beds into the Triassic Ceratite sediments*. A sharply defined boundary of this kind is rather a proof of the transgressive deposition of the Triassic upon the palæozoic strata of the Salt Range. Geologists who have worked in European Russia are acquainted with quite a number of instances where, notwithstanding the absence of a recognisable lithological boundary, a transgressive superposition of this or that sediment on sediments of older date has been proved by palæontological data. I cite here only the classical profile on the river Popowka near Pawlowsk where the discovery of Trochilisca in the upper portions of homogeneous argillaceous limestones has sufficed to prove the existence of Devonian sediments upon Lower Silurian strata without a well-marked division line between them. Those geologists also who have occupied themselves with the Mesozoic deposits of Russia will remember quite a number of instances where, within a succession of sediments of which it was supposed that they had been deposited uninterruptedly in the same sea-basin, the existence of considerable breaks was established later on, breaks which pointed to a transgressive deposition of younger strata upon others which, though lithologically similar, were chronologically far removed. Confining myself to these remarks, it appears to me that the facts adduced by Noetling do not possess the force of convincing proofs of a gradual replacement of a Permian sea of the Salt Range by the Triassic, and that the palæontologically sharply marked boundary between the corresponding sediments speaks for a transgressive deposition of the Scythian stage on the Productus limestone.

What the relation is between the zone of *Otoceras Woodwardi* and *Ophiceras tibeticum* in the Himalaya to the profile of the Salt Range is a problem which cannot yet be solved definitely. Its parallelism with the upper horizon of the Productus limestone is based first and foremost on the identity of *Medlicottia Wynnei*, Waag., from the Salt Range with *M. Dalailamae*, Diener, which according to Krafft (Ueb. d. perm. Alter der Otoceras Stufe des Himalaya. Centralbl. f. Min., Geol. u. Pal. 1901, No. 9, S. 275-279) are one and the same species. As, however, Waagen's original specimen, according to Krafft, is badly preserved, the establishment of the identity of the two species requires confirmation on the basis of more satisfactory material. It is all the more necessary to be cautious as certain *Medlicottiæ* reminding one strongly of *Medlicottia Wynnei*, Waag., have been already found in the Artinskian strata of Russia. In any case, before the correlation proposed by Noetling (N. J. Beil. Bd. XIV, Taf. zu S. 468) can be definitely accepted, it is imperative that an unbroken palæontological connection of the zone of *Cyclolobus Oldhami* and *Xenaspis carbonarius* with the deposits containing *Otoceras Woodwardi* be established.

Summarising the discussions concerning the relations between the Upper Palæozoic formations of Russia and India, we arrive at the conclusion that the Russian Upper Carboniferous sediments belonging to the Omphalotrochus and Schwagerina horizons have to be considered as homotaxial with the Productus limestones from the Amb beds upwards to the Virgal beds inclusively. The overlying parts of the Productus limestone correspond in all probability with the Permo-Carboniferous of Russia (the Artinskian horizon *CPg* and the limestone dolomite horizon *CPc*) and possibly with the lowest horizons of the Permian. A final decision on the matter must be postponed until the Russian Permo-carboniferous fauna has been completely worked out. As far as our present knowledge allows us to judge, the existence of sediments in the Salt Range which are likely to be homotaxial with the upper horizons of the Permian of Russia is highly problematical.

In this correlation the Warcha and Dandot group (with *Conularia laevigata* and *Eurydesma globosusm*) find their place in the Middle Carboniferous division of the Ural, on the eastern slope of which the conglomerates (possibly of glacial origin) appear to be the equivalents of the Talchir boulder beds of India.

In the present state of our knowledge the following scheme of correlation of the Upper Palæozoics of the Salt Range and of the Ural and Timan mountains appears to be the most probably correct one :—

Salt Range.		Ural and Timan Mountains.	
Upper Productus Limestone (thickness about 100 meters).	Chideru beds. Jabi beds. Khund Ghat beds.	Lower Permian formations of European Russia. Limestone-Dolomite horizon *C Pc* and Artinskian deposits *C Pg*.	
Middle Productus Limestone (thickness about 100 meters).	Kālabāgh beds. Virgal beds. Katta beds.	Schwagerina horizon (thickness 50—60 meters). Cora horizon (thickness 70—100 meters).	
Lower Productus Limestone (thickness about 66 meters).	Amb beds.	Omphalotrochus horizon (thickness 60—70 meters).	
Panjāb Stage of Noetling (thickness about 200 meters).	Warcha beds (Speckled sandstone and Lavender Clay). Dandot beds. Talchir (boulder) beds.	Conglomerates and Breccias on the eastern slopes of the Ural Mountains.	Middle Carboniferous Division. Sediments with *Spirifer mosquensis* on the eastern slopes of the Ural Mountains.

After these discussions on the stratigraphical position of the Productus limestones of the Salt Range, it remains to say something with respect to the Palæozoic deposits of Djulfa, Timor, Sumatra, Lo-ping in the province Kiang-si, of the Ussuri region, and with respect to the newly discovered strata with *Lyttonia* in Japan.

The remarkable fauna of the marly limestones of Djulfa, which became first known by the investigations of Abich, has been studied lately by Arthaber after a visit, undertaken in the company of Fr. Frech, to the valley of the Araxes, where the two scientists gathered an extensive collection, which quite essentially supplemented that made by Abich. This fauna excites special interest from the fact that in it there have been found, besides types which are peculiar to the Upper Carboniferous as well as to the Artinskian strata of Russia, two types of Ammonites. species of *Gastrioceras* which remind one strongly of some Upper Carboniferous and Artinskian forms (*Gastrioceras Abichi* which is near *G. Suessi*), and Ceratites-like Ammonites (*Otoceras, Hungarites*). Such apparent mixture of two faunas of different types gave rise to the conjecture that in the extensive suite of marly limestones we had in reality to deal with two palæontologically different horizons. After a personal inspection of the profiles of the Araxes valley Arthaber does not deny the possibility of such a state of things, but he observes correctly that it is impossible to form a final opinion on the matter without at first studying the extensive series of marly limestones bed by bed. A hurried visit like the one paid by Arthaber and Frech to the Araxes valley rendered such a mode of procedure quite impossible. For this reason Arthaber considers it possible that the whole of the Djulfa fauna is contemporaneous. If we grant the correctness of this view, we may consider Arthaber's deduction as sufficiently proved, according to which the marly limestones of Djulfa are of the same age as the Khund Ghat and the Jabi beds; but we must not forget at the same time the stratigraphical relationship of the sediments of Djulfa and of the Artinskian deposits of Russia.[1] However this may be, the question concerning the two faunas of the Araxes profile must at present remain open, and in the same way we cannot expect a satisfactory solution of the problem of the relationship

[1] The occurrence of the genera *Otoceras* and *Hungarites* in the fauna of Djulfa is not of paramount importance for the assumption of a younger age, for Ceratite-like forms are also found in the Upper Carboniferous deposits, as has been pointed out already.

of the marly limestones of Djulfa to the Upper Carboniferous formations, before the necessary material has been collected for a systematic exploration of Transcaucasia.

Whilst we may have reasonable doubts on the stratigraphical position of the fauna of Djulfa, we can assert with the greatest confidence that the fauna of Timor, which has been worked out by Beyrich and Rothpletz, is of the same age as the Artinskian deposit of the Ural. We are justified in this conclusion by the great resemblance of the two faunas, which has not escaped Rothpletz, as well as by their striking agreement (especially with regard to the brachiopods) with the Schwagerina beds of East Russia, which points to a close stratigraphical relationship of the shales and limestones of Timor with the Upper Carboniferous deposits of Russia.

As far as Sumatra is concerned, the existence of equivalents of the Upper Carboniferous strata of Russia could be surmised from the treatise of Roemer, and a paper by Fliegel furnishes further materials for comparison; but unfortunately the latter author has had to deal with material which was not collected by himself, and in consequence of this he is not in a position to assign the various forms to definite horizons. In any case I am of opinion that Fliegel was amply justified in the conclusion that in Sumatra deposits exist which correspond to the Moscovian stage as well as, to a certain extent, to the Upper Carboniferous of Russia.

From the island of Borneo there are known Upper Carboniferous sediments which may correspond to the Schwagerina deposits of the Ural. The same position is probably occupied by the limestones of Tenasserim which contain plenty of *Moellerinæ* accompanied by a Productus of the type of *Pr. sumatrensis*, Roem. Passing over a number of localities in Tonkin and Southern China, where partly Middle, partly Upper Carboniferous deposits exist, we meet with the richest Upper Carboniferous fauna in the province of Kiangsi near Lo-ping, a fauna, which was discovered by Richthofen and worked out by Kayser. This fauna, whose age appears to me to be most probably the same as that of the Schwagerina strata of Russia, awakens our interest by the discovery in it of *Richthofenia* and *Lyttonia* and serves as a connecting link between the Salt Range and the Ussuri region, where, as we shall see presently, the resemblance with the fauna of the Productus limestone is particularly striking.

With respect to the limestones cropping out in the vicinity of

Vladivostok, the sum total of our knowledge was contained in a communication which I had made on a small collection gathered by Margaritow at the Tawaisa bay, north-east of Vladivostok in the innermost angle of the Ussuri bay. By the expedition of D. Iwanow, which started the exploration of the Ussuri region in 1888, interesting supplementary material has been got together from the limestones of the Tawaisa bay as well as from other localities of that area, and it will be shortly described by me in a separate work. For the present, the following statements will suffice.

A rich palæontological haul was made in the Tawaisa bay, where, according to a communication of D. Iwanow, light-grey, coarsely crystalline limestones crop out, the most instructive section occurring near the southern cape of the bay. The upper portions of the limestone are of a uniform grain, and very strong clayey partings are rare. But the more one approaches the deeper horizons, the more frequent become intercalated flints and clays, which alternate with thin layers of limestone. The lowest horizons consist of calcareous sandstones and siliceous-argillaceous slates of a green colour, which rest on brecciated or conglomeratic rocks. The series of the upper limestone comprises not more than 25 meters in a total of 50 meters. In the collection of Iwanow the fossils are not accompanied by any statement of the strata in which they were found, but the adhering fragments of rock render it possible to state that the clayey layers are specially rich in crinoid stalks, bryozoa and corals, as well as in impressions and cores of *Productus Cora*, d'Orb. On the whole the same forms repeat themselves, it appears, throughout the whole series. Of the brachiopods which occur here the following may be mentioned:—*Hemiptychina inflata*, Waag., *Notothyris nucleolus*, Kut., *Camarophoria Margaritovi*, mihi, *C. Purdoni*, Waag., *Rhynchophora Nikitini*, mihi, *Hustedia remota*, Eichw., *H. indica*, Waag., *Spiriferina cristata*, Schloth., *Spiriferella Keilhavii*, Buch., *Spirifer fasciger*, Keys., *Sp.* aff. *alatus*, Schloth., a *Martinia* of the type of *M. semiglobosa*, mihi, *Reticularia lineata*, Mart., an *Enteletes* near *E. hemiplicatus*, *Productus Purdoni*, Waag., *Pr. irginæ*, Stuck., *Pr. asperulus*, Waag., *Pr. Wallacei*, Derby, *P. Weyprechti*, Toula, *Marginifera typica*, Waag., *M. ovalis*, Waag.

The same limestone overlying a conglomerate has been met with by D. Iwanow between the mouths of the rivers Mai-chä and Zymuchä in the inner angle of the Ussuri bay, and here *Camarophoria*

Margaritovi, mihi, *Camarophoria*, sp., *Reticularia rostrata*, Kut., *Productus irginæ*, Stuck., and *Pr. Cora*, d'Orb., have been found. In this limestone a great quantity of *Fusulinæ* are met with, which are distinguished by their large dimensions and the great number of whorls (17-18, even 20).

Particularly strongly developed are the limestones in the valley of the Sutschan, where they have been followed up for a distance of 45 versts (to the village of Frolowka), and from them is derived an interesting find—a beautifully preserved specimen of *Richthofenia lawrenciana*, de Koninck. According to Margaritow's statement the same limestones crop out on the right bank of the river Schite-chä. A similar limestone has been brought back by Iwanow labelled "Anutschino am Fl. Daubi-chä. Kalkstein-Schlucht," and in it occur valves of *Productus Purdoni*, Dav., and of a *Marginifera* which is very like *M. typica*, Waag. On the west coast of the Amur bay. near a place called Koreiskiye Myssy, there has been found on a coast terrace a piece of black limestone which enclosed *Lyttonia tenuis*, Waag., *Spiriferina cristata*, Schloth., *Thamniscus timanicus*, Stuck., and other less satisfactorily preserved *Bryozoa*. An entirely similar limestone crops out on both banks of the river Mangutai about 20 versts above the point where it falls into the Amur bay. According to Iwanow the limestone has here a thickness of 120 meters, and notwithstanding its appearance, somewhat differing from that of the limestones of the Tawaisa bay and of the river Mai-chä, it harbours the same conspicuous *Fusulinæ* in company with the same brachiopod fauna: *Camarophoria Margaritovi*, mihi, *Spiriferella saranæ*, Vern., *Spiriferella Keilhavii*, Buch, *Spirifer Hardmani*, Foord, *Productus porrectus*, Kut., *Pr. Weyprechti*, Toula. From this it follows that we are not yet in possession of definite stratigraphical data to guide us in the settling of the relationship of the limestones which crop out sporadically in the southern parts of the Ussuri region, but that their palæontological character remains pretty uniform all over the territory explored by Iwanow, and consequently we may, without incurring any serious risk, ascribe to them, at least provisionally, the same age. On the whole 27 brachiopods have been reported from the above-mentioned limestones of the Ussuri region, of which 16 are identical with inhabitants of the Schwagerina horizon of the Ural and Timan. Comparing our fauna with the one described by Waagen from the Salt Range, we find that 6 species are common to the Amb beds, 6 to the Katta beds, 11 to the Virgal beds, 9 to the Kálabágh beds, 7 to the Khund Ghat beds, 5 to the Jabi beds, and 2 to the Chideru beds. From this comparison we can hardly arrive at any other conclusion than that the fauna of the South Ussuri region corresponds in age on the one hand to the Schwagerina strata of Eastern Russia, and, on the other hand, to the Virgal beds and perhaps partly to the Kálabágh beds of India It is interesting to note that all those species which give our fauna its peculiar features (*Lyttonia tenuis*, *Hemiptychina inflata*, *Marginifera typica*, *Richthofenia lawrenciana*) belong to the number of those which occur either exclusively or at least mainly in the beds of the Salt Range referred to above.

Hence the fauna of the South Ussuri limestones furnishes us with a further proof that the Schwagerina deposits in the east of Russia are in no case older than the Virgal beds of the Salt Range. Besides the limestones referred to, there are found in the collection of Iwanow ash-grey calcareous sandstones, which crop out between Chatunitschi and Mnogau-dobnaja and which are palæontologically only ill-characterized, since the fossils found in them are mostly cores With certainty have been only determined *Productus Purdoni*, Waag., *Spirifer fasciger*, Keys , and *Productus* aff. *subquadrato*, Morris. I do not know in what relation these sandstones stand to the limestones. It is, however, not impossible that they overlie the limestones and that they correspond to the Artinskian sediments of Russia.

A great resemblance to the Upper Palæozoic sediments of the Southern Ussuri region can apparently be traced in the corresponding strata of Japan. Unfortunately the available data are at present very scanty. It is known that the strata crop out for about 8 degrees along the meridian; and as regards their composition we notice a short remark of Gotsche's, who states that at the basis there lies a white crystalline limestone with wollastonite; this is covered by breccias with crinoid stalks, followed by a ferruginous limestone, which is overlaid by grey limestones with crinoid stalks and *Fusulinæ*. Higher up follows a grey limestone without crinoid stalks but with *Fusulinæ*, and finally the whole is capped with a dark limestone, with large *Schwagerinæ*. These palæontological data communicated by Gotsche are very scanty and do not supply us with definite clues. Of greater interest are in this respect the discoveries made by Japanese geologists, about which, however, only little has yet been published, but among the little is still something which is capable of supplying us with definite hints with respect to the age of the Palæozoics of Japan.

It is particularly a paper by Yabe[1] which deserves notice and in which he describes two *Lyttoniæ* found in the mountainous district of Kitakami in the province of Rikuzen. The author believes the specimen which he discovered in the slates of Matsukawa near Kezennuma to belong to a new species, *Lyttonia* sp. nov., whilst he names the one from the calcareous sandstones near Yakejima *Lyttonia* cf. *nobilis*, Waagen. According to the statements of Jimbo the sandstones of Yakejima enclose besides *Lyttonia* cf. *nobilis* and numerous other brachiopods also remains of crinoids, and rest on the limestones of Kobama, in which the caudal shield of a *Phillipsia* was found, which resembles those discovered in the clay-slates of Maiya in the province of Rikuzen. These slates immediately overlie limestones with *Schwagerinæ* and *Fusulinæ*. Yabe draws therefrom correctly the conclusion that the calcareous sandstones of Yakejima are somewhat younger than the limestones, and he places them in line with the middle Productus limestone of India. According to my own opinion, this correlation could be rendered still more definite if we declare the sandstones of Yakejima, which in all probability correspond to the Artinskian deposits, to be equivalents of the Kálabágh or the Khund Ghat beds and the Schwagerina limestones, similarly to the Southern Ussuri limestones, as homataxial with the Virgal beds. It is highly probable that the sandstones in the southern Ussuri region, with which we dealt above, correspond in age to those of Yakejima. However that may be, there is one fact of great geological significance which cannot be abolished, and that is the remarkable resemblance which exists, notwithstanding the vast distances, between the Upper Palæozoic sediments of Eastern and Northern Russia on one side of Eurasia and those of both the coasts of the Sea of Japan on the other side.

Concluding Remarks.[2]

In the preceding summary it has been demonstrated with sufficient clearness that the type of the Upper Carboniferous Fauna of

[1] H. Yabe. The Brachiopod Lyttonia from Rikusen province. Journ. Geol. Soc. of Tōkyō, Vol. VII, No. 79 (1890).

[2] (Pages 740—742.)

Russia repeats itself within the vast area which comprises the Polar Region, North and South America, India, Central Asia, China, the Indian Archipelago, the Southern Ussuri region, and Japan. In a similar manner the type of the Russian Fauna is met with in the sediments which are homotaxial with the Artinskian horizon and which occur in the Mediterranian region (Trogkofel, Neumarktl, Sicily, the Pyrenees), in the Salt Range and the Himalayas, in quite a number of localities in Central Asia, in Japan, in North America (Texas), and in Western Australia. Notwithstanding the existence of various differences in the character of the contemporaneous faunas, these differences find their explanation not so much in a difference of age, as in differences in the facies of the respective faunas or in local causes.

I have endeavoured to show that the *Brachiopoda* are not without value for the determination of the age of the various numbers of the Upper Palæozoics, and that the peculiar features of the latter, which it is possible to establish by a study of their brachiopods, go hand in hand with the characters which can be observed in other classes of invertebrates in connection with definite geological moments Without again referring to the whole of the facts which have been dealt with before, I draw attention only to the discovery, made quite lately in various parts of the globe (Russia, North America, India, Japan, and Australia), of representatives of such a remarkable organism as *Helicoprion*, which unquestionably characterizes a very definite moment in the history of the Earth. All these finds have been made in deposits which from their invertebrate fauna we have grounds to consider as homotaxial with the Russian Artinskian sediments.

Starting from this conception of the character of the Upper Palæozoic fauna and of its universal type, we may draw for ourselves the following general picture of the distribution of land and sea during the Upper Carboniferous epoch. The commencement of this epoch is marked by a retreat of the sea from the greater part of Western Europe (except the Mediterranean region), from the eastern flanks of the Ural and the northern coast of North-East Siberia The Russian sea, which at the same time contracted within the boundaries of Russia, formed part of the extensive Arctic Ocean which, as may be assumed, washed the shores of Greenland and the northern parts of the American Archipelago. In the south, on the side of the Black Sea, it communicated with the Mediterranean, at least during the second half of this epoch, and towards the south-east it had maintained its connection with the extensive Chino-Malayan sea which had already been in existence during the Middle and Lower Carboniferous epochs. We have even grounds for surmising that the Chino-Malayan sea communicated in the west with the Mediterranean across the present Irān and Armenia. The great likeness of the Upper Carboniferous fauna of Russia with that of South America can hardly be explained by supposing the former to have penetrated to the regions of the Amazon river, to Peru and Bolivia in a roundabout fashion by way of the Arctic Ocean. It is, indeed, very probable that Fr. Frech is right when he contends that the Mediterranean has extended westwards up to the Eastern boundaries of the American continent of to-day.

Towards the close of the Upper Carboniferous period the invasion by the sea of the area occupied at the present day by continents had reached its maximum, and during the following Artinskian epoch the sea commenced to retreat.[1] Still more pronounced is this change at the commencement of the epoch during which the Permian sediments of Russia were deposited, and towards the end of the Permian period we notice undoubted instances of marine invasion only within a limited area of the present continents (in. Russia and West Europe, and perhaps in the Polar regions and the western parts of North America) whilst the larger portion of the sediments laid down during the Permian Period is, as far as known, of continental origin.

In my treatise I have also discussed the boulder beds of the Salt Range and of Australia,[2] and the results at which I have arrived in this respect harmonise in the best possible manner with the remark of Ed. Suess [3] with which he concludes his general discussion of the Carboniferous sediments of Central Asia: "Accordingly the whole of the deposition of the boulders which can be observed all round

[1] In some places, for instance on the northern coast of the Chino-Malayan sea, the latter advanced, as is testified by the discoveries of D. Klemenz in the Dsungarian Gobi (Verhandl. d. Russ Kais. Min. Ges. Bd. XXXVIII, Prot. S. 44-45).

[2] When I speak of boulder beds, I understand by them only those which belong to the lower marine series of New South Wales and the corresponding strata of Victoria. In Australia glaciation set in repeatedly during upper palæozoic times.

[3] E. Suess, Beitr. zur. Stratigraphie Central Asiens, S. 11 (439).

the Indian Ocean in South Africa, India, and Australia took place during the Carboniferous Period." Possibly it would not be rash to place with Feistmantel the horizon of the boulder beds somewhere near the boundary between Lower and Middle Divisions of the Carboniferous System.

NOTE ON THE GLACIATION AND HISTORY OF THE SIND VALLEY, KASHMIR. *By* R. D. OLDHAM, A.R.S.M., F.G.S., *late Superintendent, Geological Survey of India.* (With plates 11—16.)

The first twelve miles of the Sind Valley, from its entrance to the neighbourhood of Kangan, is straight and open, the ends of all the spurs being truncated along a fairly straight line. This feature has been regarded as characteristic of glacier action, but it is also produced by streams when they are flowing at or near the slope of equilibrium, and have consequently little or no tendency to deepen their valleys; in these circumstances lateral erosion sets in, and the ends of the spurs are gradually truncated where they project into the belt over which the windings of the stream tend to make it wander.

In the case of the Sind valley glacial action is excluded, for this lower part is filled, to a depth of some 300 feet, by stream deposits, the greater part consisting of fine-grained alluvium. This has been cut into terraces by the river, and the terraces, like the existing stream bed, are covered by waterworn boulders. It is difficult to believe that a glacier could have flowed over this deposit, nor is there any sign of one having done so, and it is equally inconceivable that this deposit, which is a continuation of the karewahs of Kashmir, could have been formed and again eroded since the retreat of the glaciers.

Above Kangan the valley begins to narrow, and accumulations of rock-fragments, some of large size, are seen in places, lying on the fine-grained alluvium. These might be taken for moraines, but, on examination, they appeared to me to be in every case accumulations formed by torrents issuing from a narrow side valley in their neighbourhood.

At the junction of the tributary, between Haru and Sambal, there is a great accumulation of débris, much of it large and sub-angular, which may well be moraine material, but may equally be due to occasional floods from the narrow and steep-sided valley of the tributary.

Above the bridge at Sambal the road runs at first over a deposit of rounded and waterworn boulders, but soon enters one composed of angular or slightly rounded fragments of rock, among which limestone fragments occur in an abundance and of a size which is difficult to attribute to the stream of the Sind river. There is consequently a suggestion of glacial action, but the surface conformation is that of a series of fans, issuing from the side valleys. If, then, the material in the valley is to any extent moraine, the original surface has been completely obliterated by the main and tributary streams of the Sind, while there has also been a large admixture of local débris brought down from the hills to the north.

In this connection may be mentioned an instructive instance showing the care which must be exercised in assuming glacial action without the strongest evidence. About a mile above the Sambal bridge the road crosses a small ridge, composed of angular rock-fragments of all sizes, which presents many of the characteristics of a moraine. A closer examination of the ground shows that it is not one, for on either side of the ridge there is a drop from a higher to a lower level; the line of this drop takes a regular curve, and the ground at its foot is palpably an old river terrace. In the centre of this curve issues the valley of the tributary flowing past the village of Boorphrar, as marked on the map, and the ridge referred to above is composed of the flood deposits of this torrent, among which are sub-angular blocks of 20 feet in diameter. This deposit is now being cut into by the stream, which is crossed immediately after the ridge is passed, and so a comparatively narrow ridge, steep on both sides, has been formed.

So far no very certain or definite signs of glacier action were seen, but it is right to say that I was not expecting to see any, and did not make a close search. In the stretch of the valley next entered, which extends from about a mile below to about two miles above Gund, the evidence of glaciation is striking and abundant. About a mile below Gund the Sind passes through a short rocky gorge, cut through a spur whose top is rounded and scored and grooved in a manner which is unmistakably the result of glacier action. On the left bank of the Sind this spur is covered on the top- and the down-stream side with moraine of the type known as ground-moraine.

A part of the village of Gund is built on a great *roche moutonnée*, and the hillside is smoothed and striated for a height of about 500 feet above the bottom of the valley, the glacier having probably reached another hundred feet above this level. It must be noted that the weathering of exposed rock-surfaces is evidently a rapid process in these regions, and the smoothed and striated surface, once cleared of its protecting layer of soil, is very soon destroyed, principally by the action of frost in opening the joints which traverse the rock, and so causing it to break away in small fragments.

The tributary valley which joins the Sind at Gund is a deep-cut, precipitous-sided gorge whose form is evidently due to the erosion of the stream it carries, but on climbing the hillside, and entering this valley at a height of about 400 feet above the village, where it is more open, the spurs are found to show a smoothing and striation, due to a glacier which issued from the valley. We have, in fact, an older open valley once filled by a glacier, in which a narrow rocky gorge has been cut since it was freed from ice; remains of this older valley can be traced, though obscurely, up both branches of the tributary, but the original surface form has been almost entirely obliterated by erosion.

Above Gund signs of glaciation, in the shape of smoothed and striated surfaces, are numerous for a couple of miles, till the road climbs on to a rocky spur, whose end has been scarped by the river and whose upper surface is smoothed and striated in the most typical manner. From this spur an excellent view of the valley is obtained, exhibiting all the features which have been recognised as due to the action of glaciers. There is the broad, open floor, from which numerous *roches moutonnées* rise, and on the right or north side of the valley the rock walls rise steeply to a height of about 600 feet above the river, and the steep, often perpendicular, walls still show, in many places, the smoothing due to ice. From the top of this steep wall the hillside slopes back at an angle due to weathering, and not at that due to the erosion of a glacier.[1]

The opposite side of the valley does not show this so well, but there are two good reasons for the difference. In the first place, being the south side of the valley, and having a northerly aspect, it is still covered with a dense forest which hides, to a large extent, the minor surface features, while the opposite side of the valley, facing south, is almost devoid of trees. In the second place, the valley is not straight,

[1] As the capacity of a glacier to give rise to a distinctive valley section has been doubted, it may be mentioned that in the north-west Himalayas, where valleys due to river erosion pure and simple are found side by side with those which have carried a glacier, the trough-shaped section of the lower part of the latter corresponding to the portion formerly filled by the glacier is very conspicuous in contrast to the absence of such in the former. This statement requires the qualification that the trough form is only seen where the conditions for its preservation are favourable; being an essentially unstable form, once the glacier is removed, it is only preserved where cut in a rock not liable to rapid disintegration, and where the conditions of the stream which succeeded the glacier have been such that the glacier valley form has neither been obliterated by deposition nor destroyed by erosion.

but bends round an open curve, and the north is the outer or convex side of this curve; it is against this side of the valley that the greatest force of the ice would be exerted and its greatest effect produced.

The trough-shaped valley can be traced to near the Sambal bridge, below which it becomes indistinct, and as this is the first place where moraine material was first recognised with any degree of probability, we may conclude that the Sind valley once held a glacier which extended at least as far down stream as Sambal.

The preservation of the surface forms produced by the old glacier is to be attributed in part to the nature of the rock near Gund, this being a hard, schistose slate, very quartzose in places, and in others distinctly hornblendic, but to a larger extent it is due to the fact that the changes of level which have taken place since the retreat of the glacier happen to have left this stretch of valley comparatively unaffected. Consequently, the old glacier floor has neither been buried beneath stream deposits, nor has the river obliterated the marks of glaciation by cutting a deep gorge out of the old valley.

As Rewil village is approached the valley becomes filled with stream deposits, and no more *roches moutonnées* are seen rising from it; the northern side still rises steeply and the steep face shows, in places, signs of glaciation. These are seen conspicuously on the bridle-path which leads along the hillside between Kulan and Gagangir, and the trough shape of the lower part of the valley can be recognised as far as that village.

At Gagangir the slates give place to limestone, forming a narrow band, separated from the main mass of limestone to the north by a ridge composed of altered volcanic rocks, in the manner indicated in Mr. Lydekker's map. This ridge of volcanics forms a barrier across the continuation of the Sind valley, which not only makes a bend in its general direction at this place, but also changes in form and character. On the west side of the Song valley, joining the Sind just above Gagangir, the limestone ridge rises with a smooth and somewhat rounded surface, which looks as if it might have been smoothed by a mighty glacier coming down the main valley. As the Song valley itself is a narrow, steep-sided and irregular gorge, evidently formed by stream erosion, and unaffected in its form by ice, and as the smooth surface referred to is so steep as to be quite inaccessible, it is more probably due to a fault surface, from which the overlying rock has come away in a landslip.

However this may be, the outer end of this spur does seem to have been rounded by ice, and a little further up the main valley there is what appears to be part of an old glacial floor, now cut into by the river, which flows in a rocky, vertical-sided gorge. Above this, little more than a mile from the village of Gagangir, no trace of glaciation can be seen; the valley narrows in and the river flows in a rocky gorge, cut at first along the boundary between the volcanics and the limestone, but afterwards turning across the strike and penetrating the high range formed by the volcanics in a narrow and precipitous-sided gorge, through which the river runs in a succession of small waterfalls and foaming rapids.

At its upper end the gorge ceases suddenly and the road enters a valley, on one side of which rise hills composed of limestone with its associated shales and quartzite; on the other side a steep slope, composed throughout of moraine material, rises to a height of 500 feet, and beyond can be seen a broad and open valley, more like the lower part of the Sind valley and quite unlike the gorge just passed through.

The nature of this gorge is unmistakable; it is not only a river-cut gorge, showing no signs of ever having carried a glacier, but it is a gorge which the river is evidently still engaged in deepening. When I first passed through it, I was inclined to attribute its presence, between two more open parts of the valley, both of which retain, in greater or less degree, traces of having once carried a glacier, to a recent elevation of this part of the Sind valley, and to a consequent cutting down of the bed of the river, with a concomitant obliteration of the traces of glacial action. As will be seen in the sequel, this hypothesis proved untenable, but the fact remains that the band of volcanic rocks, which crosses the Sind at this place, is a zone of special structural elevation. The map and section published by Mr. Lydekker are enough to prove this, and whether his interpretation of the section, as a fold, or whether the alternative explanation of the presence of the volcanics by faulting, be accepted, in either case the line along which they occur must have undergone a greater amount of elevation than the limestones on either side.

There is also evidence that part of this elevation is of very recent date, if it be not still in progress. Just above the first or lower bridge at Sonamarg there is a terrace, whose upper surface has an elevation of about 50 feet above the present river bed. It is composed throughout of well water-worn pebbles and boulders of the same average size, and the fact that the deposit extends down to the level of the stream shows that, before it was formed, the gorge must have been cut down to at least its present level, that elevation then took place at a greater rate than the downward erosion of the river could keep pace with, and that afterwards the elevation either ceased, or became slower, and the river, being once more able to lower the barrier across its path, cut down into its old deposits.

To the left or east of the river rise the old moraines on which the summer settlement of Sonamarg is situated, whose description it will be convenient to defer for the present, while continuing that of the main valley of the Sind. Crossing the lower bridge, the road traverses the outer fringe of the Sonamarg moraines, between which and the village of Sonamarg is a broad plain of river gravels, some 30 to 40 feet above the present level of the river and, apparently, a continuation of the terrace already mentioned.

On the opposite (north) bank of the river, deposits of a very different character are exposed in section; they consist of fine gravel, are distinctly and thinly bedded, and the beds, though practically horizontal, have a perceptible, though very small, upstream dip. These deposits are indurated, while the coarser river gravels on the opposite side are still loose; they are evidently the older of the two and, from their nature, must have been deposited, either in a shallow lake, or in a stretch of the river where, from one cause or another, the gradient had been reduced till the stream was no longer able to transport anything coarser than fine gravel.

Just above the bridge and opposite the village of Sonamarg, the river has cut into a low, round-topped spur of rock, whose upper surface has a form suggesting that it had been rounded by ice, though it is too weathered to preserve any striæ. A little higher up a spur comes down from the other side, and the valley, as a whole, is narrower here than it is below or above.

Proceeding up the valley, this preserves its open character and general straightness, but beyond this there is no certain sign of its having carried a glacier. Just below Viligrar are a series of moraines, evidently formed by a glacier which issued from the Viligrar valley; on the other side of this valley moraines can also be traced, though not so distinctly, yet the valley itself is a typical river-cut gorge with vertical sides, in every respect except in the absence of interlocking spurs. The absence of signs of glaciation in this side valley, in the face of the evidence that it carried a glacier at a later date than the main valley, renders the absence of definite signs of glaciation in the latter easily intelligible, and shows how little the thin-bedded limestones of these hills is adapted to preserving the effect of a glacier.

From the next side-valley, that of Kokuron, there issues a great barrier running out into the valley: no distinct lateral moraines can be seen, but the uneven surface and the angular nature of the débris of which it is composed, suggest that this may be a moraine, though the possibility of its being an accumulation of flood deposits is not excluded.

Talus fans are common all along the sides of the valley from Sonamarg on, and above Kokuron they become almost continuous on the right, or northern, side. A section disclosed by the stream at Ranga shows that some of the slopes which look like talus are not so in reality, but due to a sloping-off of the solid rock and the forming of an even slope, thinly covered by débris, which may be distinguished as pseudo-talus.

As Baltal is approached the character of the valley changes once more, being bounded by the lofty cliffs (*bal*) from which Baltal derives its name. Here the straight and open valley which has been followed, comes to an end, the direction of the main valley takes a bend to the right, and at the bend it is joined by the tributary up whose valley runs the road over the Zoji-la.

Taking the main valley first, this is open and filled at the bottom with débris, and bounded on both sides by lofty cliffs of bare rock. The stream now flows at the foot of those on the left, or western, side of the valley, and these are consequently the steepest, show the most freshly exposed surface, and are least cut into by tributary ravines. It is evident, however, that the stream at one time cut at the base of the cliffs opposite, and has been forced away from them by the increasing amount of débris which fell from them. In time the process will doubtless be reversed, and the increasing amount of material falling from the increasingly lofty cliffs on the left bank will force the river over to the opposite side of the valley.

The open valley only extends for a little over a mile from the Baltal rest-house, the valley then bifurcates and each of the two tributary valleys immediately becomes a precipitous-sided rocky gorge. I ascended that along which there is a track leading to Amarnath; in ordinary years it is said to be impassable, but this year, on account of the unusually large snowfall, it was possible to make one's way up the gorge, over the unmelted snow which bridged the stream. The ascent is a rapid one for about 3 miles, in which the rise was 2,000 feet by a not very trustworthy aneroid, and certainly not less than that. At this level the valley becomes more open, and it was possible to see up it for a couple of miles further, but even here there was a narrow, rocky and winding snow-filled gorge, of unknown depth, cut in the older, open valley.

Looking back out of this valley, from near the confluence, the bare cliffs bounding the opposite side of the valley are seen to be crowned by the grassy slopes of the Rainur grazing grounds, and from one of the small valleys draining these slopes the stream falls to the Sind in a series of waterfalls which have a height of over 2,500 feet.

Here there is no longer any trace of glacier action in the valley; whether it ever carried a glacier or not, its present form is due to the action of the river alone, and, whatever may be the cause, the river is evidently still deepening its valley above Baltal, while the two separate streams above the confluence are still more actively deepening their channels, and have not yet reached that stage, attained by their combined waters, when they can commence to erode laterally and widen their valleys.

At Baltal the main valley is joined by the tributary up which runs the road over the Zoji-la, and at once a very different type of valley is met with. Narrow and steep sided, the view up it is blocked by a precipitous spur running down from right to left, and immediately behind this another, equally precipitous, runs from left to right, along whose face runs the track, dignified by the name of a road, by which the traffic over the Zoji-la is carried This is a typical river gorge, and on entering the valley its character is still more clearly developed, as a narrow, precipitous-sided and winding gorge, in active process of erosion by the stream it carries.

The ascent from Baltal is very steep to the crest of the spur mentioned above, which is regarded as the crest of the pass, though the summit level, on the watershed, is some two miles further on. From the crest of this spur an open and tolerably straight valley stretches to the north-east, but in the floor of this valley is excavated a narrow, almost vertical-sided, gorge, the upper course of the stream which flows to Baltal. This gorge continues to the junction of the Kanipater stream, and up the valley of that tributary; it probably extends a little way further up the main valley, diminishing in depth, but cannot reach very far, for in the gaps which had melted through the snow, I could see that the stream flowed over a flat and gravelly bed, having a gentle gradient.

The valley here is, once more, of the glacier-shaped type, with a broad floor; steep sides showing glacial smoothing rise from this floor, the valley sides sloping back from the level of the old glacier surface and the minor tributaries entering by waterfalls.

The actual watershed is determined by a fan of débris, coming down from the mountains to the north-west, and beyond it the valley continues of the same type and appearance, with the sole difference that the waters are flowing north-east instead of south-west.

The evidence of "capture" is very distinct; not only have we the absence of any defined watershed, and the continuance across the present watershed of a valley form due to streams and glaciers which once flowed from the south-west, but there is the palpable disparity between the size of the valley and the stream it carries on the one hand, and the signs of recent and rapid erosion on the other. The Sind drainage is evidently cutting back into that of the Gumber, but it must be admitted that the site of the watershed seems to be determined by some other cause. For a mile on the Sind valley side there is no sign of erosion, the stream flows over a flat of débris, and at one place it is interrupted by a small lake, or rather pool; moreover, the descent from the watershed, though gentle, is distinctly steeper on the side of the Gumber than on that of the Sind valley. From these facts it seems probable that the position of the watershed has been determined by earth-movements and the raising of a barrier across the valley which once drained into the Gumber, and it is important to note that the site of the present watershed lies very near the axis of the anticline of older slates, which separates the permo-triassic limestones of the Sind from those of the Gumber valley.

The important question of the date and extent of the changes which have taken place in the distribution of the drainage will be considered further on, after this description of the Gumber valley.

At Mechoi a glacier comes down to about half a mile from the road, and has evidently extended almost down to where the road now runs, as is shown by the heaps of moraine material, still bare of any vegetation, which lie scattered over a glaciated rock-surface. The tongue of this glacier lies in a comparatively narrow and somewhat

V-shaped trough of rock, whose sides are smoothed and striated, but below the end of the glacier the valley, as a whole, is seen to have a tolerably flat rock floor, and in this floor is a narrow depression which continues up into the hollow occupied by the glacier. The present state of the glacier is one of retreat from its original extension, as is shown by the lofty lateral moraines between which it lies, but it seems as if there had been an even more complete retreat of the glacier than at present during which a stream gorge had been cut in the more open glacial valley, and that this gorge had afterwards been occupied and partly modified in form by the glacier, when it once more advanced. This supposition is supported by the character of the main valley below Mechoi.

Immediately below the Mechoi valley there are no less than eight distinctly marked ridges, radiating into the main valley, and representing old lateral moraines of the Mechoi glacier. On the opposite (up-stream) side of its valley no moraines are seen, except some small remnants clinging to the hillside, and it is probable that this is due to their having been removed by the action of the stream, which is here forced over to the right or southern side of the valley by a great talus fan coming down from the opposite hills.

The moraines just mentioned are truncated at their further end by the stream, which is cutting its bed downwards, and the extension of the Mechoi glacier across the main valley, which they indicate, must have held back the downward erosion of the valley above it. There is indication of a temporary lake having been formed, in some very false bedded deposits of fine gravel, which are exposed in section on the left bank of the river, opposite Mechoi.

Below Mechoi the Gumber valley assumes a very different aspect to that of its upper portion. There is, first, a broad, open valley, whose floor is marked by the rounded tops of spurs, which stretch out from the steeply rising hills on either side; and secondly, cut into this more open valley, is a narrow, winding valley, with steep sides, in which the river flows. Here the broad, open valley, which continues on much the same general slope as that of the valley above Mechoi, may be regarded as the glacier valley at the time of the greatest extension of the glaciers, and the narrow, winding valley as having been formed by the river, after the retreat of the glacier.

This, however, is not all. It will be seen from the map that the Vachkarya and Gumber streams flow parallel to each other for over a mile above their junction; in other respects the map somewhat misrepresents the facts, for the two streams are not separated by a high ridge, but by a low and narrow spur, not over 200 feet in height, while the Vachkarya stream flows through a broad, grassy plain, known as Minimarg. The road crosses the spur referred to over moraine material, and enters the Vachkarya valley, which in spite of the smaller size of the stream it carries, is larger and broader than that of the Gumber on the other side of the spur.

There is here a diversion of drainage, the continuation of the deep-cut valley of the Gumber below Mechoi is through a gap, now filled with moraine, at the head of the Minimarg plain, and the history of what has taken place seems to be as follows:—First, we have a valley, occupied by a glacier for long enough to allow of its impressing the peculiar features due to its action on the valley; this valley, as left by the glacier, was open and comparatively flat-bottomed, the bed level being about the tops of the spurs now projecting into the valley. Then came a general retreat of the glaciers, and river erosion set in, cutting a gorge in the bottom of the trough left by the glacier; next the glaciers advanced once more, as is shown by the smoothing and striation of the sides of the deepened valley, but not for long enough to materially alter the form and destroy the traces of stream action in it.

This narrow, deepened valley was joined by that of the Vachkarya, near the head of what is now the plain of Minimarg, and, as the glaciers retreated, that of the main valley retreated faster than that of the tributary, or, perhaps, after the retreat there was a fresh advance, during which the Vachkarya glacier filled the main valley with its lateral moraine and forced the stream of the Gumber to take the course it now follows. So it comes to pass that the Vachkarya occupies the valley which once carried the waters of the Gumber and its own, while the main river has been forced to cut for itself a narrow, rocky gorge and to find its way back into the main valley along what was originally part of the course of a tributary.

The Vachkarya valley, which has been mentioned above, is a deep and narrow, rocky valley, whose sides have been smoothed and striated by a glacier. Looking up this from the junction with what is, as has been explained, really the valley of the Gumber, the view is soon obstructed; but the bend of the valley, round the spur obstructing the view, is gentle, and above this the valley combines the general straightness and gentle curves of a typical glacier valley, with the general V-shapes of one eroded by water. There is a tendency to a U-shape at the bottom, below which is a purely river-formed rocky gorge, whose cliffs vary from 10 to 30 feet in height.

A noteworthy point about this valley is that the tributary valleys all enter it at a height of 200 feet or so above the bottom of the valley, and, whether this overdeepening of the main valley is due to ice or water, there can be no doubt that the lower part of the valley has been occupied by a glacier, for its sides show the smoothing and striation characteristic of that agent.

The most probable explanation of the form of the valley is that this is mainly due to the action of water, and that the stream-formed gorge has been partially modified by a glacier, which did not last for long enough to convert the valley into the typical glacier form. It has already been shown that the original Gumber valley, as left by the glacier after the retreat from its maximum extension, was deepened by river erosion; this would lower the outlet of the Vachkarya valley and set up downward erosion in it, but, on account of the smaller volume of its stream it might well have failed to reach that stage at which a stream commences to widen its valley, before the glacier once more advanced and filled the stream-cut valley, rounding off the projecting angles of the spurs and straightening the general course, without having time to obliterate the general features of the valley, before it again retreated. It may be noticed in this connection that the upper part of the valley, which must have been longest under ice, shows a more perfect approach to the typical glacier form than the lower, and that in the lower valley there are still indications of an older, more open and trough-shaped valley graded to the level of the oldest glacier valley of the Gumber.

The lowering of the base level of the Vachkarya has enabled it to extend its drainage area; it is probable that this has taken place in more than one direction, but the only one actually seen by me is its capture of a part of the Mechoi drainage. Not far above the point where the Vachkarya enters the Minimarg plain, there is a tributary valley, or ravine, entering on its left, or western side, in which is a small hanging glacier with a very large moraine. This ravine has cut back part of the ridge bounding the Mechoi drainage area, whose glacier now overhangs the watershed. It is very probable that the removal of the hills on the eastern flank of the Mechoi glacier is the explanation of the very marked contrast between the large lateral moraines left by it in the Gumber valley, and the insignificant size of the lateral moraine formed during its last extension.

Below Minimarg the quartzose and hornblendic schistose slates give way to limestone near the junction of the next tributary—that called Kharo on the map. From this on to Matayan the river flows through permo-triassic limestones and associated rocks, and all trace of glaciation of the rocks is lost. The valley is open and steep-sided, but the extensive flats of gravel show that its present form is largely due to lateral erosion by the river, and the only traces left by the glacier which once filled it are the moraines which cling to the hillsides.

Having described the Sind and Gumber valleys and their relation to each other, there still remains for consideration the question of the amount of the increase of the former by capture of the head waters of the latter.

To a certain extent this is obvious. Looking up the valley of the Sind, from the ascent to the Zoji-la, the precipitous sides of the valley are seen to end in the grassy slopes of Harbaguan and Rainur; on these can be seen valleys whose open section, grassy slopes, and comparatively gentle gradients are abruptly truncated by the bare, rocky precipices which descend to the valley of the Sind.

The larger of these valleys has the trough shape characteristic of a glacier valley, and still has a small glacier at its head, while the abrupt truncation of its lower end shows that the valley must formerly have extended to a greater length than at present The elevation of the valley bottom is distinctly above that of the Zoji-la, and there can be little doubt that the drainage of these elevated valleys flowed into the Gumber before the Sind valley penetrated so far, and diverted into its course the whole of the drainage which now flows past Baltal.

Below Baltal there are no obvious signs of diversion of drainage, and for further evidence of the original extent of the Gumber valley we must return to Sonamarg and its moraines.

Between the two bridges the track, leading to the summer resort of Sonamarg, leaves the road and leads over uneven ground, which can easily be recognised as an old moraine, till it reaches an amphitheatre surrounded by a continuous ridge of lateral and terminal moraines, within which a series of lesser moraines, marking successive stages in the retreat of the glacier, can be seen. The source of the material composing these moraines is not far to seek, for they lie at the mouth of the Darnar valley, on whose sides small, hanging glaciers can still be seen, while the valley itself shows, in a most typical manner, the straightness, the trough-shaped section, the smoothed and striated sides, and the entry of lateral valleys at a height above the bottom, which are characteristic of valleys that have been shaped by glaciers In the present instance these features are rendered more conspicuous by the fact that the valley has been excavated along a band of comparatively soft, shaly rocks, lying, with vertical bedding, between hard limestone on the one hand and the still harder altered volcanics on the other.

As the Atlas of India is on too small a scale to represent these moraines satisfactorily, I have made a plane-table sketch of their disposition which will serve to illustrate what follows.

The first point to be noticed, and one that is even more striking on the ground than in the plan, is that these moraines must have been formed by a glacier which flowed in the direction which is now up the Sind valley. This is well seen when the moraines are viewed from one of the spurs in the Shokdar valley, when the Sind river can be seen flowing, in its deep-cut valley, from left to right, while behind it the moraines slope down from right to left.

Even more striking is the manner in which the lateral moraines on the left, or south, side of the old glacier stretch right across the entrance of the gorge through the ridge of volcanic rocks. The bed of this gorge, as has been mentioned, lies 500 feet below the crest of the moraines; moreover, the whole of this depth is cut in moraine material, showing that the valley must have been excavated to its present depth before the glacier began to form its moraines. It is consequently difficult to escape the conclusion that the present gorge of the Sind could not have existed at the time when the glacier extended over Sonamarg, for, had the gorge been then in existence, the glacier would naturally have flowed out in that direction, instead of building up its moraines across the gorge.

This conclusion involves the supposition that the drainage from Sonamarg escaped to the northwards, and as the lowest point on the watershed, in the Zoji-la, has an elevation of about 2,500 feet above the village of Sonamarg, it also involves a change of relative level, of at least this amount, since the formation of the Sonamarg moraines. Large as this elevation may seem, yet, in view of the evidence which exists to show that there have been changes of level in the Himalayan region in historic times, it is not in itself impossible. I have already mentioned that there appears to be a certain amount of tectonic reversal of drainage on the southern side of the watershed, and in the absence of direct evidence, in that neighbourhood, of the amount of change of levels which has taken place, the hypothesis that this reversal has extended as far as Sonamarg cannot be summarily rejected, and must be examined in greater detail.

The first point to be considered is the fact, indicated by the course of the lateral moraines, that the glacier flowed straight across the mouth, without any part of it flowing down the gorge of the Sind This shows that the gorge could not then have existed in its present form, but it does not show that the course of the drainage was to the southward, for there has certainly been an elevation of the rock-barrier below Sonamarg, leading to the accumulation of river gravels above it, since the cutting of the deep channel through the moraines, and it is conceivable that before or during their formation there might have been a larger and more rapid elevation of the range to the south, making it easier for the glacier to flow up-stream into the open valley of the Sind, than down its gorge.

It is, however, obvious that if this be the explanation, then the gradient of the river above the gorge must have been diminished, a lake might easily have been formed, and in any case there should be a great accumulation of river deposits up-stream of the rising barrier. Now the Shokdar valley to the west of the Sonamarg has a very different aspect to that of the Darnar-valley. Instead of the openness and trough-shaped section of a glacier valley, it is narrow, winding, has a V-shaped section in its lower part, and, moreover, is filled to a great depth by stream gravels, now cut into by the stream which formed them. The absence of signs of a glacier having filled this valley is explained by the lesser elevation of the hills bounding it, and is reflected in the fact that while there are now no glaciers on its slope, the south side of the Darnar valley still shows four small glaciers ; it is therefore easy to understand that when the Darnar valley carried a glacier throughout its length, the lower beds of the Shokdar valley were free from ice.

The filling of the Shokdar valley with stream deposits fits in with, and indeed demands, the formation of a barrier in a down-stream direction, and the depth of this filling, being approximately the same as the height of the Sonamarg moraines, is consistent with the idea that this barrier lay across the gorge, but if we turn to the main valley we find no filling of river deposits, such as would be demanded by this hypothesis. The valley is open, at a lower level than the moraines, and devoid of any trace of the accumulation of river gravels which must inevitably have been formed had a barrier of 500 feet in height been raised across the Sind valley at a time when it possessed anything like its present extent. The features of the valley are consistent with the hypothesis that the Darnar glacier and its moraine formed the barrier that gave rise to the accumulation of stream deposits in the Shokdar valley, but they do not fall in with the alternative hypothesis that the barrier was common to the drainage area of both valleys.

The supposition that the Sind river followed its present course through the hills south of Sonamarg having been excluded, there remains only the alternative hypothesis of a complete reversal of the course of the drainage, an hypothesis which is supported by direct evidence in its favour, in addition to that against its alternative.

Mention has been made of the traces of glacier action on the rocks near Sonamarg village, and of the moraine material there. This moraine consists, so far as the larger blocks are concerned, almost entirely of volcanic rocks; up-stream, beyond the old fort of Abrim Khan, the valley bottom is strewn with large blocks of the same rock, which show signs of having been water-worn, but still retain, to a large extent, the subangular form due to weathering. The river gravels above Sonamarg are full of boulders and pebbles of the same rock, but they get rarer and rarer up-stream.

An inspection of Mr. Lydekker's map shows that the band of volcanics which crosses the Sind below Sonamarg, also crosses the upper waters of the river in Harbagwan; it is, consequently, conceivable that pebbles of this rock might find their way, down the valley, to the neighbourhood of Sonamarg, but it is not conceivable that pebbles derived from this source should grow more abundant; larger in size, and less waterworn in a down-stream direction. The only other source for the fragments of volcanic rock above Sonamarg is the range to the south, and whether they are derived solely from old moraines, or were in part carried by water, their presence involves an easterly flow of the drainage, which now flows west past Sonamarg.

It is possible to determine the precise stage in the history of the formation of the moraines at which the drainage was first directed into its present course. The outer moraines, up to that marked

A B C on the plan, are all breached by a series of gaps, through which a stream still flows, fed by percolation from the moraines, but quite incapable of having formed the valley through which its course to the Sind lies. This valley is comparable to what might be expected from a stream of the volume and power of that which now flows from the Darnar valley, and may safely be attributed to the glacier stream, flowing over and among the moraines and having power to move even large blocks of stone. The moraine which lies across the head of this valley has a low gap at B, and the form of the ground on the outer side of this gap shows that a stream once flowed through it, but a stream of much less power than that which carved its course through the older moraines, for, instead of cutting a channel for itself, it was merely able to spread out the glacier débris in a fan of deposit.

This moraine marks the time when the larger part of the water flowing from the glacier had already been tapped by the Sind valley. It is probable that there was no stream flowing directly from the glacier to the Sind, but this river had cut back, through the rock barrier, into the moraine, and received an increasing proportion of the sub-glacial water of the Darnar glacier, by percolation through the moraine. By the time the glacier had retreated to the limit, which it only held for a short time, marked by the next succeeding moraine the glacier stream seems to have changed its course and flowed to the Sind, for there is low ground and a truncation of the large moraine just south of the point C The gorge had by this time been fully established. but not cut down to within a couple of hundred feet of its present level. At a later stage the glacier retreated still further, the stream was established in its present course, and has since cut down into the old moraine as the bed of the Sind was lowered.

It will be seen from this that the exceptional perfection in which the moraines have been preserved is directly due to this diversion of drainage, and the consequent drying up of the old glacier stream, which would otherwise have cut its way through them.

Though it is easy enough to determine the exact stage in the formation of the Sonamarg moraines at which the Sind valley captured their drainage, it is not so easy to determine which of the epochs of greater extent of the glaciers they belong to. Evidently not the first and greatest of the three recognised in the Gumber valley, for at that time the glacier must have extended the whole length of the valley, so that the choice remains between the second and third of the epochs of glaciation. The extension of the glaciers during the second epoch seems to have been much greater, as compared with their present size, than is indicated by the Sonamarg moraines; on the other hand, these represent a greater comparative extension of the glaciers than the moraines which project into the Gumber valley at Mechoi. There are, however, three considerations which must be borne in mind in this connection ; firstly, the collecting area in the Darnar is much greater than in the Mechoi valley, and a lowering of the permanent snow-level would cause a comparatively much larger extension of the glaciers ; secondly, the Darnar valley has certainly lost some of its area by the cutting back of the Aro valley, and though the amount so lost may be small in comparison to the whole area of the valley, it is large in proportion to the possible collecting ground of the glacier, besides—what is more important—including higher ground than is now found along the watershed ; thirdly, the precipitation is greater in the Darnar than in the Mechoi valley, and if the proportion of each which falls as snow were equally increased, there would be a greater extension of the glaciers in the former than in the latter case.

These considerations lessen the weight of the apparently much greater extension of the glacier, and are supported by the fact that there are no well-marked moraines in the Darnar valley which could be ascribed to the third advance of the glaciers, as should be the case if the Sonamarg moraines belonged to the second. It is therefore probable that they were formed during the latest, and least, of the three epochs of greater extension of the glaciers.

Whatever may be the epoch of their formation, it is, geologically speaking, extremely recent, and the facts and considerations detailed above show that within the time which has elapsed since that epoch, the Sind river has lengthened its course by 20 miles and added 150 square miles to its drainage area, while the range to the north of it has undergone an elevation of at least 2,500 feet as compared with the valley at Sonamarg, whose drainage formerly flowed through the valley now forming the Zoji-la.

This is the extreme extent of the changes which can be established with certainty, but there is good reason to suppose that the original extent of the Gumber valley was even greater than that which has been shown. In the first place the valley between Sonamarg and Ranga has undergone little or no change in form since the reversal of its drainage, as is shown by the position and preservation of the

Niligrar moraines, yet in form and size it does not seem to be accounted for by the drainage of the Darnar and Shokdar valleys alone, and so suggests that it may have carried drainage from beyond the hills to the south of those valleys. In the second place, there is the form of the tributary-valleys of the Sind; at least as far down-stream as that which joins below Sambal, they have an upper portion, which is open and has a moderate gradient, and a lower, steep, precipitous-sided gorge which leads down to the Sind. This feature might be attributed to the conservative action of the glaciers which certainly filled the upper portions and held back the downward erosion of the valleys, but it is evident that the feature must be in part antecedent to the glaciation of the main valley between Gund and Gagangir, which is most probably attributable to the first great extension of the glaciers, or more doubtfully and at latest to the second.

The feature is in kind, though not in degree, the same as is seen in the Upper Sind, above Baltal, and is very likely due to a similar cause, that is to say, the upper valleys of the tributaries are the remains of old valleys which once drained northwards to the Gumber and have not yet been reached by the retrocession in levels caused by the cutting back of the Sind valley.

EXPLANATION OF THE PHOTOGRAPHS.

PLATE 12.—*Gorge of the Zoji-la.*—The summer track leads over the slopes of the hillside to the left, the winter track over the snowdrifts in the gorge, which is cut in vertically-bedded limestone and slate. The gorge shows the steep sides and interlocking spurs characteristic of a river-cut gorge.

PLATE 13.—*View in the Sind valley above Baltal.*—The cliffs shown in this view are on the left side of the valley and about 2,500 feet high. They mark the cutting-down of the valley bed since the diversion of drainage, and above them are the smoothed, grassy slopes of the original valley, now forming the Rainur grazing ground. This photograph also illustrates the influence of structure on erosion; the streamlet in the centre happens to flow over a synclinal fold, where the limestone has been compacted by compression and has, consequently, been unable to cut back its valley, and falls over a series of waterfalls; to the right of the picture the limestones have been bent into an anticline and a similar stream flows in a ravine which it has cut out of the hillside, thereby obliterating the grassy slopes of the old valley.

PLATE 14.—*General view of the Sonamarg moraines, taken from one of the spurs in the Shokdar valley.*—This shows how the glacier must have flowed from right to left of this picture, while the Sind river now flows from left to right in the valley cut through the moraines.

PLATE 15.—*View of the Shokdar valley, showing the river gravels accumulated in it when the outlet was blocked by the Sonamarg glacier.*—These have now been cut into terraces during the re-excavation of the valley.

PLATE 16.—*The Mechoi glacier.*—Shows the open valley formed by the glacier at its greatest extension, the narrow gorge cut in the floor of this valley during the retreat of the glacier and now filled by the existing glacier. Also the lateral and terminal moraine formed when the glacier had a slightly greater extension than at present.

ON THE OCCURRENCE OF A SPECIES OF HALORITES IN THE TRIAS OF BALUCHISTAN. *By* E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.* (With plates 17 and 18.)

During the summer of 1901, an interesting specimen of an ammonite belonging to the catenate group of the genus *Halorites* was found in the triassic shales of Balúchistán. The matter was reported in time for insertion in the General Report of the Geological Survey for 1901-02, but it had to be omitted in consequence of the very narrow limits which were then prescribed for that publication.

The surveys of 1901 disclosed an unexpected large development of triassic beds in the highlands situated south of the Upper Zhob Valley. The hills that border the Upper Zhob both to the north and south exhibit great structural complications, and include a vast number of different geological formations. Two of these, however, cover an area far greater than all the others. They are two groups mainly consisting of shales, the Kojak shales of tertiary age, and the triassic shales, situated, respectively, north and south of the valley. These rocks preponderate to such an extent, that in a rapid traverse one is apt to think that they are the only rocks present, as it is easy to overlook all the others, whose outcrops are comparatively small and discontinuous. This explains how it is that, south of the Zhob, some extremely interesting outliers of highly fossiliferous tertiary rocks of eocene and oligocene age compressed into narrow synclines have escaped the attention of previous observers.[1]

The intense pressure to which both the Kojak shales and these triassic rocks have been subjected has induced the development of slaty cleavage, rendering both formations at first sight very much alike. This circumstance, as well as a great paucity of fossils, have misled several observers into looking upon them as identical.

Mr. Griesbach having established the connection of the shales north of the Zhob, through the Toba plateau, with those of the Kojak range whose eocene age he had been able to settle from the presence of

[1] General Report for 1901-1902, page 32.

bands containing nummulites, came to the conclusion that the shales south of the valley also represent the same formation.

Subsequently the hills south of the Zhob were visited by Mr. Oldham. No fossils were met with, but from considerations based upon lithology and stratigraphy Mr. Oldham was led to regard them as triassic, and they are thus represented in the map illustrating the second edition of the Manual of the Geology of India. At the same time, the fossil evidence in connection with the Kojak shales was disregarded, on the supposition that, just as in the triassic area, the nummulitic beds only constituted outliers, and the conclusion arrived at was that the Kojak shales themselves are triassic or upper palæozoic, as is also conspicuously indicated on the same map. Nevertheless, Mr. Oldham expressed some doubt as to the identity of the shales on either side of the Zhob Valley, thus hinting at the true solution of the problem.[1]

On resuming the survey of Balúchistán in 1892, Mr. Griesbach maintained his former opinion that the shales south of the Upper Zhob are the same as the Kojak shales. This time, however, some undoubted triassic and upper palæozoic fossils were found. But as they occurred in loose blocks removed from their original site, an attempt was made to reconcile their presence with the supposed tertiary age of the strata, on the assumption that they might be derived from "blocs exotiques."[2]

The question was finally settled during my survey of 1901 by observing that the triassic fossils are uniformly distributed throughout the whole mass of shales, as mentioned in the General Report for 1901-02. A thorough examination of the rocks, which would have been impracticable during the previous surveys, disclosed some well-marked differences in the lithological characters exhibited respectively by the Kojak shales and the older group. Both, indeed, consist largely of slaty shales, usually of a greenish tinge, but sometimes slate-coloured or of various pink or red tints. In both systems there are numerous intercalations of narrow bands of harder strata standing out on weathering as small ledges or ridges. But while, in the case of the Kojak shales, these harder bands are calcareous sandstones of the same greenish hue as the associated shales, in the triassic beds they are dark compact limestones, nearly black on the fractured surface.

The fossils in the triassic beds are not numerous and belong only

[1] Manual of the Geology of India, 2nd edition, p. 143, footnote. Annual Report for 1901-02, p. 31.

[2] Records, G. S. I., Vol. XXVIII, p. 8. General Report for 1901-02, p. 13.

to a small number of species By far the least uncommon is a species of *Monotis* closely allied to or identical with *M. salinaria*. The impressions of its thin shells are locally abundant, sometimes coating the entire surface of slabs of shale, whose regular intercalation amidst the surrounding strata can leave no doubt as to their belonging to the formation whose age is thus established. They have been found at numerous places scattered all over the vast outcrop of the shales. Almost anywhere, indeed, a little searching is soon rewarded by the discovery of a few specimens, always of this same species, and, although the fauna is singularly poor, these slates and shales are not quite so barren as the Kojak shales.

These observations dispose of the necessity of regarding the fossiliferous fragments as "blocs exotiques," and it follows that the entire group of shales south of the Upper Zhob is triassic and distinct from the tertiary Koják shales.

The discovery *in situ* of a specimen of *Halorites* still further confirms these conclusions, and assists in determining the exact age of these rocks. The specimen was obtained in the western portion of the triassic outcrop, where it extends into the Pishin district, near the locality called Mach on the accompanying map, north of a narrow syncline of tertiary rocks which yielded large collections of eocene and oligocene fossils. I noticed that the *Monotis* shells were exceptionally abundant and well preserved at this spot, and after several days of systematic search, I found a single specimen of *Halorites* lying on the surface. It is a species belonging to the group of the *Catenati continui*, and is, so far, the only Indian representative of that group. The spot where it was found consists of rolling ground situated along a rather flat watershed, so that there was no possibility of its having been transported from a distance. It is quite similar in colour and in the constitution of its matrix to the shales which formerly enclosed it.

This is the only ammonite that I ever obtained at the actual spot where it had weathered out of the shales. A few more specimens belonging to other genera, but none so well preserved as the *Halorites*, were picked up from time to time, but always amongst boulders transported along the river beds that traverse the triassic hills. This was also the condition under which Mr. Griesbach discovered the specimen of *Didymites*, described as *Didymites Afghanicus* by E. von Mojsisovics, who from its presence concluded that the Alaunian stage must be represented in the Zhob district,[1] thus ascribing to the strata that yielded that fossil a later age than to the richly fossiliferous zone of *Halorites* in the Himalayan trias which is regarded by Mojsisovics as belonging to the lower portion of the Juvavian. This geologist drew attention to the remarkable circumstance that the numerous species of the Himalayan beds are all acatenate forms, while strata of the same age in Europe contain catenate forms as well. From these circumstances, and from the presence of catenate species at a higher horizon in the Swearing slates of California, Mojsisovics came to the conclusion that these catenate forms must have migrated gradually in an eastward direction amidst the waters of the Tethys. "As the connection between the Mediterranean Province and the Pacific basin can only have been made by means of the Tethys, the thought occurs to one that the emigration of the catenate *Halorites* to the Pacific basin may have taken place only in the middle or upper Juvavian period."[2]

So far as it goes, the evidence afforded by the single specimen of *Halorites* found in Balúchistán is in harmony with these conclusions. In the Himalaya the horizon of *Monotis salinaria*, which is presumably Alaunian, is newer than that which yielded the numerous specimens of non-catenate *Halorites*. There is good reason, therefore, to conclude that the *Monotis*-bearing shales of Balúchistán are of the same age as the *Monotis salinaria* zone of the Himalaya. The catenate *Halorites* found in Balúchistán is therefore newer than the acatenate specimens of the Himalaya, thus agreeing fully with the theory above referred to.

Considering the great width of their outcrop, the thickness of these shales must be considerable, although it is evident that they are many times repeated by folding. Yet, considering the homogeneity of their scanty fauna, as represented by the single but ubiquitous *Monotis*, one is driven to the conclusion that they represent but one stage of the Trias. This great thickness of shales was probably deposited in a comparatively short time in a rapidly sinking area.

It is interesting to note that in the midst of the triassic area there occurs at one point an outcrop of slates associated with Fusulina limestone. The section is so obscured by close folding, with the development of slaty cleavage, that it is difficult to decide whether this

[1] Pal. Indica, Ser. XV, Vol. III, pp. 44 and 141.
[2] Pal. Indica, Ser. XV, Vol. III, p. 147.

juxtaposition is due to faulting or merely results from unconformity, but the complete absence of strata of intermediate age there, or anywhere near, leads one to infer that whatever may be the structure at that particular place, a stratigraphical break intervenes between the Upper Palæozoic and Upper Trias.

The *Halorites* and a specimen of the *Monotis* are represented on the accompanying plate. These specimens will be described by Prof. Diener, in whose hands they are at present, together with triassic collections from other parts of India.

The small map illustrates the situation of the triassic outcrop. It is compiled from the latest surveys.[1]

[1] In this map the same colour has been used to represent the intrusive rocks of the Deccan trap and the contemporaneous flows or agglomerates of that same formation. The latter are only represented in the neighbourhood of Hamandun, their outcrop is situated on the map north-west of the word ' Kushnob."

EXPLANATION OF PLATE 17.

1. *Monotis* cf *salinaria*, Br., from the hill south of Ashna Ghara (Lat 30° 36', Long 67° 32') on the road from Pishin to Ziarat.

2. *Halorites* sp., found about one mile south-east of Muhammad Azim (Lat. 30° 38', Long. 67° 36').

NOTES ON THE GEOLOGY AND MINERAL RESOURCES OF MAYURBHANJ.[1] *By* P. N. BOSE, B.Sc., F.G.S., *late Deputy Superintendent, Geological Survey of India.*

Area examined.

Mayurbhanj has hitherto been a blank on the geological map of India not having been previously examined by any geologist. The State is divisible into a hill-area and a plain-area. Last season (December, 1903, to March, 1904) my work was practically confined to the former, which comprises the Bamanghati and Panchpir sub-divisions, and the western and north-western portions of Mayurbhanj proper—an area of about 2,400 square miles.

Tertiary rocks near Baripada.

As only a very small portion of the plain country has been surveyed, I have but little to say concerning it in this report. There is, however, one matter of great interest which should receive a passing notice. At Molia, two miles south of Baripada (the capital of the State), there are exposed in the bed of the Barabalang river, yellowish and yellowish-brown limestones which are very rich in fossils referable to the genus *Ostræa.* Mr. Pilgrim of the Geological Survey of India who has studied a few specimens which I sent him, has not succeeded in identifying them with any known species of *Ostræa.* He has, however, detected "affinities with Tertiary forms, *viz.*, *Ostræa multicostata*, Deshayes, from the upper part of the eocene of the Paris basin, and *O. Torresi*, Phillipi, from the Magellanian beds of Patagonia which are probably oligocene in age .... The specimens somewhat resemble an undescribed species of *Ostræa* found in the upper Nári beds of Baluchistan which are probably oligocene in age." Considering that no fossiliferous rocks later than the Gondwanas (except those of subrecent age) have hitherto been known in eastern India in the vast area between Pondicherry and the Khasi hills, the find is of great importance in Indian geology. From what little I have seen of the contiguous district of Midnapur, there is, I think, every possibility

[1] Mayurbhanj, or Morbhanj, one of the States of Orissa, Bengal, lying between 21° 17′ and 22° 34′ lat., and between 85° 42′ and 87° 14′ long.

of fossiliferous strata similar to those of Molia being found there. The Molia limestones pass above into thinly stratified horizontal, or but slightly rolling, greyish white or very pale, green clays. Similar clays are met with in all the sections about Baripada under a variable thickness of laterite averaging about 15 feet.

Hill country: Stratigraphical Summary.

The hill country presents several well-defined ranges, rising occasionally to peaks between three and four thousand feet above the sea-level. It is needless to say that the examination of such a vast area, a large portion of which is covered by thick, almost impenetrable jungle, was of a somewhat cursory character, especially as a good portion of the short season was devoted to the slow work of mineral exploration by diggings.

Throughout the area the sub-metamorphic series appears to be in superposition upon the metamorphic, the latter being exposed by the denudation of the former. The gneiss is at places highly granitoid, and true granite is by no means infrequent. Mica schists with pegmatite veins prevail in the area about Bongarposi in Mayurbhanj proper. The gneissic rocks are much intersected by dykes of basic and intermediate rocks. The principal constituents of the sub-metamorphic series are quartzites, phyllites, and micaceous, talcose, hornblendic and trappean-looking schists. The quartzites are sometimes banded and not unfrequently hæmatitic as well. Conglomerates are rare The quartzites are occasionally blackish, and dark slaty or sub-schistose quartzites attain considerable development at places. As in the case of the gneissic rocks, trappean intrusions abound throughout the area. The prevailing strike is north-western, and the dips usually point eastward

Iron.

The chief mineral wealth of the State consists in its iron-ores, which are possibly among the richest and most extensive in India. In the Bamanghati sub-division, they occur in quantity at the following localities :—

(1) At the foot and along the slopes of the Gurumaishani hill in all directions except the eastern over an area of about eight square miles.

(2) Near Bandgaon in Saranda-pir.

(3) At the foot and along the flanks of the Sulaipat-Badampahar range on the southern border of the Bamanghati sub-division from Kondadera to Jaidhanposi, a distance of some twelve miles.

In the Panchpir sub-division the ores occur at diverse places along the foot of the hills which fringe the Simlipahar range on the western and southern side from Kamdabedi and Kantikna to Thakurmunda, a distance of twenty-five miles.

In Mayurbhanj proper iron-ores occur at several places in the Simlipahar range, as near Gurguria. They were also encountered at places in the submontane tract just adjoining the Simlipahar range on the eastern side—as near Kendua (close to Sorsobila), and at a place two miles west of Baldia.

The ores except when transported occur almost exclusively in the transition series, especially in association with banded hæmatite quartzites. Usually, they consist of hæmatite and limonite. But thick and rather extensive deposits of magnetite were met with at the foot and along the flanks of the Gurumaishani hill, south-east of Kolaisila, east of Sundol, and also near Kotapiti. Magnetite also occurs in quantity near Bandgaon and in the Kondadera-Jaidhanposi area. The average ore in the Bamanghati and Panchpir sub-divisions will probably be found to contain above 60, if not above 65, per cent. of metallic iron.

It is very difficult to make even an approximate estimate of the quantity of available iron-ores. But it would probably be no exaggeration to say, that a practically inexhaustible supply for several furnaces on a modern scale may be safely depended upon. The ores are easily accessible from the Sini-Ghatsila section of the Bengal-Nagpur Railway, and a line of 25 or 30 miles would tap the Gurumaishani area. As will be noticed later on, limestone in the form of tufa occurs at several places in and close to the iron area.

There are a good many families of smelters in the ground described above, and the iron they turn out is held in high estimation by the people. But the furnaces are the smallest and the bellows the least powerful of any I have seen in use anywhere in India. The smelters, therefore, select the softest ores, which are generally very far from the best. When I showed them a few pieces of magnetite, they pronounced these to be mere stones and quite useless as iron-ores!

Red and yellow ochres occur at places and are much used by the Sonthals in painting their houses.

Iron-pyrites occur in some abundance disseminated in talcose and trappean-looking schists in the transition series at places, as at the Mailamghati on the Dhálbhúm border.

Manganese.

Traces of manganese ore were found in laterite close to banded, blackish quartzites near Kuliana in Mayurbhanj proper. I failed, however, to find it in quantity.

Gold.

Gold is washed for in the Subarnarikha river on the northern border of Mayurbhanj proper, and in the Kadkai and Borae rivers in the Bamanghati sub-division There is nothing specially noteworthy about these river-washings. But, at the head waters of the Borae river about Kudersai and Sapgora there is a tract about 2 square miles in extent, where I found almost the entire alluvium to be more or less auriferous. Some fifty families of goldwashers earn their livelihood by gold-washing in this area. They just scrape off the surface soil which is usually the richest, owing probably, in part, to its being periodically replenished by wash from the adjacent hills during the rainy season, and in part to natural concentration *in situ* by rain water Nuggets are occasionally met with, but the largest shown to me as found in the area weighed half a tola.

The auriferous alluvium is of a brownish colour, and is thinly spread over micaceous and trappean-looking schists referable to the transition series I found it to contain more or less gold down to a depth of about two feet The richest placer deposits were found invariably to occur in the immediate vicinity of dioritic rocks with iron-pyrites traversed by thin irregular veins of quartz. There are no quartz-reefs in the area; and it is a curious fact that, though there are magnificent reefs outside that area, no gold is known to occur either in or near them.

West and north-west of Ruasi and Gohadongri by the Godia river and its feeder, and separated from the Kudersai-Sapgora ground by a low range of hills, there is another area of placer deposits of similar extent. The deposits here are at places 12 to 15 feet in thickness, and consist of rather gritty, brownish, stiff clay resting upon a coarse gravel bed about 3 feet in thickness. The bed rock seen at places is greyish-white micaceous schist with thin veins of quartz. At one spot (by the Banijbaran stream, a feeder of the Godia) where the alluvium was washed the gravelly layer was found to be the richest. Nuggets weighing as much as 2 to 3 tolas were reported to me as having been recently found in the area under description. It supports some twenty families of gold washers settled in it, besides casual visitors from the Dhálbhúm State.

That the placer deposits described above pay is evidenced by the fact, that they afford an easy means of livelihood to the washers who work with the primitive appliance of a small wooden dish and who are certainly far from remarkable for industry and steady work. Besides, the washers confine their operations to the surface, whereas the entire alluvium was proved to be more or less auriferous; and in one case, at least, the lowermost gravelly layer was found to be the richest. The washers are not aware of this fact; and even if they were they would not take the trouble to dig when scraping the surface serves their purpose.

Whether the deposits would be remunerative if worked on modern methods is a question which can be properly settled only by washing experiments on a larger scale than I was able to make. The best time for such experiments would be the rainy season when there would be a plentiful supply of water.

Mica.

Mica occurs in the following areas:—

(1) In the Bamanghati sub-division about Raibedi and about Tiring. The ground is gneissic and is much intersected by trap-dykes. Mica occurs in nests and strings in pegmatite veins. These were dug into at several places, but the plates obtained were everywhere small, not exceeding 2 or 3 square inches, and the excavations did not warrant the expectation of finding larger ones.

(2) In Mayurbhanj proper mica occurs near Sirsa and in the vicinity of Bangarposi, about Jamgodia and other places. The Jamgodia area appeared to me the most promising. It is composed of mica schists in which pegmatite veins are exposed at places for a considerable distance along the Sankrai river. Muscovite occurs in these veins in good-sized books, but the plates obtained from the surface, though some measured more than 8 square inches, were necessarily in

a much weathered condition. Excavations are in progress to test the quality of the mineral at depth

Limestone.

The occurrence of limestone in the form of tufa or travertine was noted at the following localities :—

(*a*) Bamanghati sub-division.

1 Rangom hill (near Beter Amda).

2 Asurghati.

3 On the southern side of Gurumaishani hill (between Sandol and Kotapiti).

(*b*) Simlipahar area : Three miles west of Gurguria.

(*c*) Panchpir sub-division : Olkader.

Yellowish fossiliferous limestone occurs in the bed of the Barabalang river at Molia, two miles south of Baripada.

Asbestos, opal, copper-pyrites.

Near Rangom hill, in the Bamanghati sub-division, on the road leading from Beter Amda to Dublabeda, there occurs vein quartz in decomposed epidioritic rocks which affect an exfoliating nodular structure. The quartz veins do not go down deeper than about two or three feet from the surface ; and in them are found opal, actinolite. asbestos and copper-pyrites. Samples sent to Mr. Vredenburg, Curator, Geological Survey of India, are described by him as being " principally opal in which are imbedded well-shaped prisms of a transparent dark-green actinolite passing along the borders of the specimens into fibrous asbestos .... The opal when seen under the microscope is found to have become largely doubly refracting, a considerable portion having been transformed into chalcedony, which is either minutely granular or else arranged into tufts approaching spherulitic structure."

Pottery clay.

The clays which have already been referred to as underlying the laterite about Baripada are generally very well suited for pottery. A sample examined by Mr. Vredenburg, Curator, Geological Survey of India, is pronounced by him to " constitute an excellent material for pottery." Says Mr. Vredenburg : " It disintegrates slowly in water yielding a plastic paste. This I made into a small lump which I burnt in an ordinary Bunsen flame, heating it to a bright red. It did not fuse, but became intensely hard, and assumed an agreeable terra cotta colour.''

Miscellaneous minerals.

Potstones occur at various places of which the following are noteworthy. They are generally the result of the decomposition of dioritic-looking rocks. But beds of steatite sometimes occur in the transition series :—

(1) In Bamanghati sub-division near Tiring on the Dhálbhúm border.

(2) Three miles west of Gurguria (Simlipahar area).

(3) Nulungi, 5 miles west of Baldia in Mayurbhanj proper. Utensils of sorts are manufactured here which have a ready sale at Baripada.

Grindstones are made at Kuliana (Mayurbhanj proper) out of the quartzites of the transition series.

Agate, flint, jasper, etc., occur in some profusion at places in the Bamanghati sub-division.

MISCELLANEOUS NOTES.

Pyrrhotite from the Kirána Hills, Punjab.

Some interesting specimens have reached the Department from the little known Kirána (Korana) hills of the Jech Doab of the Punjab, which have never been visited by any geologist since their cursory examination by Dr. Fleming, whose account was published in 1854 (in Selections from the Public Correspondence of the Punjab Administration). The specimens here referred to were sent by Mr. F. E. Cole, Assistant Engineer of the Jech-Doab Railway, who obtained them in a railway quarry at Hoondiwala Hill, Kirána Railway Station (under construction). The specimens are large blocks, up to nearly a foot in size, of a compact, homogeneous, jaspideous, semi-translucent quartz-rock of greyish-green colour, through which are scattered numerous masses of pyrrhotite, whose dimensions frequently reach one centimetre or more. The colour of the mineral is brass-yellow. It is distinctly magnetic. It contains neither nickel nor cobalt. It is difficult, without any details as to its mode of occurrence, to understand the true nature of the enclosing jaspideous rock. It consists entirely, as seen in microscopic section, of very minutely crystalline quartz.

[E. VREDENBURG.]

Vivianite in the Alluvium of Bengal.

Specimens of vivianite associated with logs of wood were found in April last in digging a tank at Jamalpur village (Lat. 22° 39', Long. 88° 45') fourteen and-a-half miles in a straight line E S. E. from Baraset Railway Station in the Baraset Sub-division of the Twenty-four Pergunnahs The logs of wood are embedded in a stiff clay of pale-blue colour, containing numerous linear impressions of small twigs or stalks. The wood in the larger logs is encrusted with, and apparently partly replaced by, a bright-blue, pulverulent mineral, presenting physical properties and yielding chemical reactions characteristic of vivianite. The depth at which the specimens were found is estimated by the discoverer as thirty feet.

[E. VREDENBURG.]

Recent or sub-recent marine bed in Calcutta.

We are indebted to the courtesy of Mr. G. F. Ross, Manager of the South British Marine Insurance Company, for one of the most interesting discoveries yet made in the alluvium of Lower Bengal. The excavations for the foundations of some new buildings shortly to be erected in Clive Street, Calcutta, have partly penetrated beyond the made ground and old foundations of former buildings, into the underlying undisturbed sediments. A stratum of large oyster shells met with, at a uniform level, throughout nearly the whole area excavated, attracted the attention of Mr. Ross, who brought the specimens to the office of the Geological Survey. On the 23rd of July Mr. Ross showed me over the ground where the discovery had been made. The trenches, so far opened, were being filled with concrete, but in one of them the section was still visible. The oyster bank at that place was only a few inches thick (probably about half a foot or less), and was situated at about five feet below the level of Clive Street. A thickness of about one foot of the underlying stratum was exposed, consisting of black mud. In all the other trenches, at the time of my visit, the concrete had been built above the level of the oyster-bed, but the heaps of mud and rubbish lying by the side of the excavations were covered with the oyster shells, indicating the presence of the marine stratum over a space of at least one hundred feet square. Mr Ross and the overseers were unanimous in declaring that the oyster bank occurred at one uniform level whenever met with. In the section visible on the 23rd, one foot, or a little less, of brown mud intervened between the top of the oyster-bed and the bottom of some brick foundations of old walls or buildings. The oyster shells are said to have been found sometimes in layers and sometimes isolated. The first statement is fully borne out by the condition of a great many of the specimens, in which the inferior valve of one oyster is fixed to the dead shell of another. A considerable proportion of the specimens are found with both valves united.

Major A. W. Alcock, F.R.S., Superintendent of the Indian Museum, to whom the specimens were shown, recognised them as identical with a large species of oyster which lives in large numbers in the mud banks near the mouths of the channels of the Sunderbands. Major Alcock mentioned, as a characteristic peculiarity, that the umbonal part of the shell and the ligamental pit often grow to a considerable length, thus enabling the animal to raise its shell above the mud in which it would otherwise be buried. This character is very well shown in some of the Clive Street specimens, in which the ligamental pit sometimes reaches a length of nearly eight inches. It is sometimes straight, or else curiously curved. Judging from their large size and robust appearance, it is improbable that these shells could have flourished much above low-water mark, implying a relative position of the sea and land decidedly different from that obtaining at present. The altitude of the Calcutta oyster-bed is scarcely ever reached even by the highest spring-tides in the Hooghly River. Sufficient data are not available to decide whether this indicates a change of level in the sea or in the land.

Scattered about the mud heaps by the side of the trenches, I picked up, besides the oysters, a number of other shells, both marine and fresh water. They include *Telescopium fuscum*, Ch., a gastropod which Major Alcock has observed living in abundance amongst the oyster banks of the Sunderbands; and species of *Arca*, *Anomia*, *Ampullaria*, *Paludina*, and *Planorbis*.

Barnacles and serpulæ were also found by Mr. Fermor, who collected a number of specimens on the 24th of July. According to information communicated by the overseers to Mr. Fermor, the fresh-water shells are found principally in the layer of mud underlying the oyster-bed.

[E. VREDENBURG.]

Pleistocene Fossils from the Ganges Alluvium.

In sinking the well foundations of the Ganges Bridge at Allahabad for the Allahabad-Fyzabad Railway, several bones were dredged up, which were sent by Mr. R. R. Gales, Engineer-in-Chief, to the Geological Survey, accompanied by a section and notes of their mode of occurrence.

The bones for the most part occur in a bed of exceedingly hard and compact calcareous conglomerate, of which the maximum thickness is 2 feet 6 inches. The bed is found at depths varying from 80 to 100 feet below low-water mark, and is covered by some 120 feet of fine, white, micaceous sand, intermixed in places with patches of clay and kankar. Beneath the conglomerate band is some yellow sand, and then hard, yellow clay with kankar nodules.

The following is a detailed list of the fossils which I have examined :—

Bos namadicus, Falconer.	Right mandible.
Do.	Right maxilla.
Do.	Right maxillary molar.
Elephas, sp.	Atlas vertebra.
Do.	Shaft of radius.
Hippopotamus sp.	Cervica vertebra.
Do.	Dorsal vertebra.
Do.	Distal end of femur.
Bos or Bubalus sp.	Tibia.
Do.	Distal end of right humerous.
Do.	Distal end of metacarpals.
Do.	Third cervical vertebra.
Cervus sp.	Left tibia.
Do.	Femur.
Do.	Antlers.
Bubalus sp.	Fragmentary skull.

The teeth of *Bos namadicus* the only ones which admit of specific identification, show certain variations of structure tending towards the recent species of *Bos*. This suggests that these beds are newer than the ancient alluvial deposits of the Narbada, in which the typical *Bos namadicus* is found. It is noteworthy that Dr. Falconer arrived at the same conclusion with regard to the age of the Jumna alluvium, after examining some fossils obtained thence in 1830,[1] and this conclusion was based on the absence of *Bos namadicus* from these deposits; the present find shows, however, that it was in existence at this period, though possessing a somewhat advanced type of structure. Assuming on the authority of The Manual of the Geology of India that the Narbada ossiferous deposits are Pleistocene, then these fossils must also be considered of Pleistocene age.

[G. E. PILGRIM.]

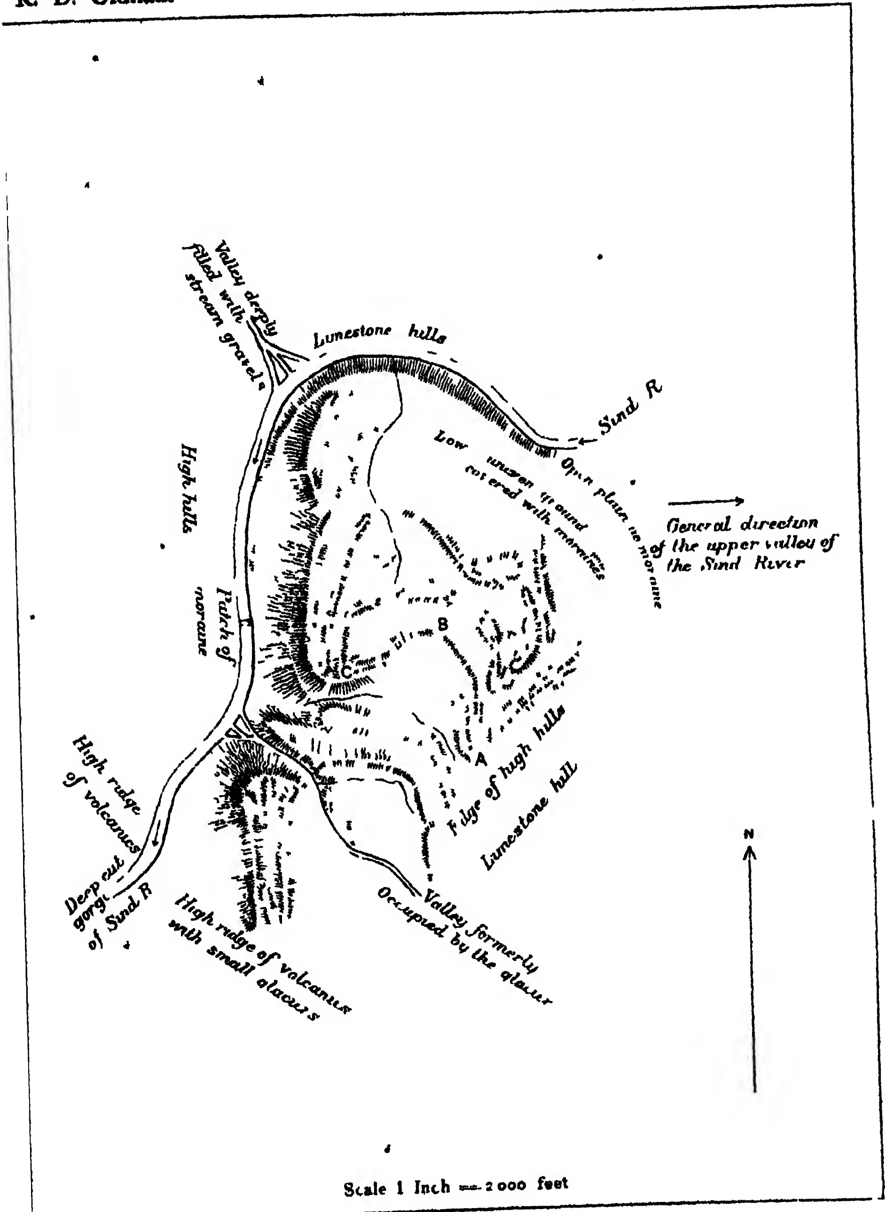
[1] Manual of the Geology of India, 2nd Edition, p. 436. Falconer, Pal. Mem. II, p. 640.

G. I. C. P. O. – No. 240, D. G. Survey, – 2-9-04. – J. Marum

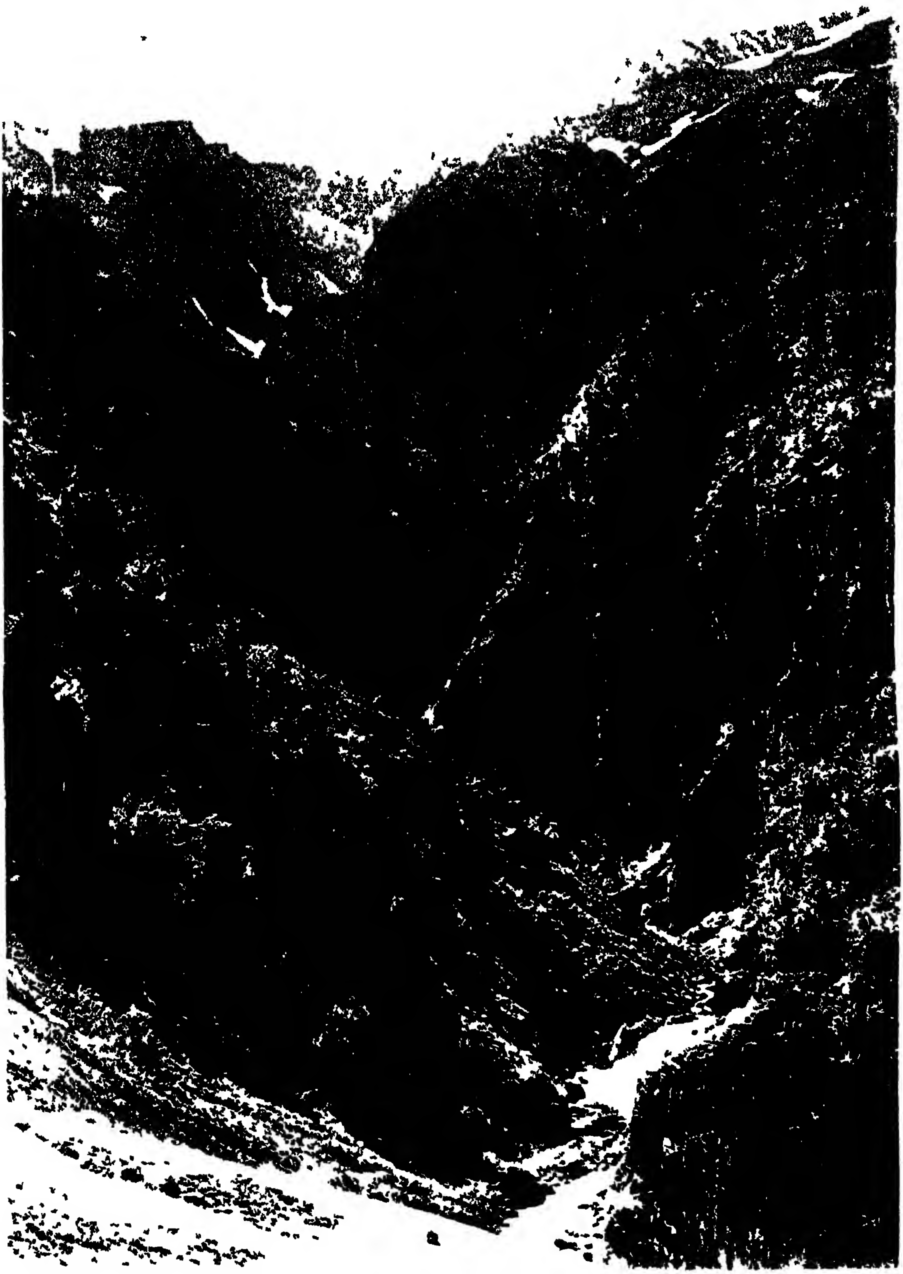
GEOLOGICAL SURVEY OF INDIA

R. D. Oldham

Records, Vol. XXXI, Pl 11



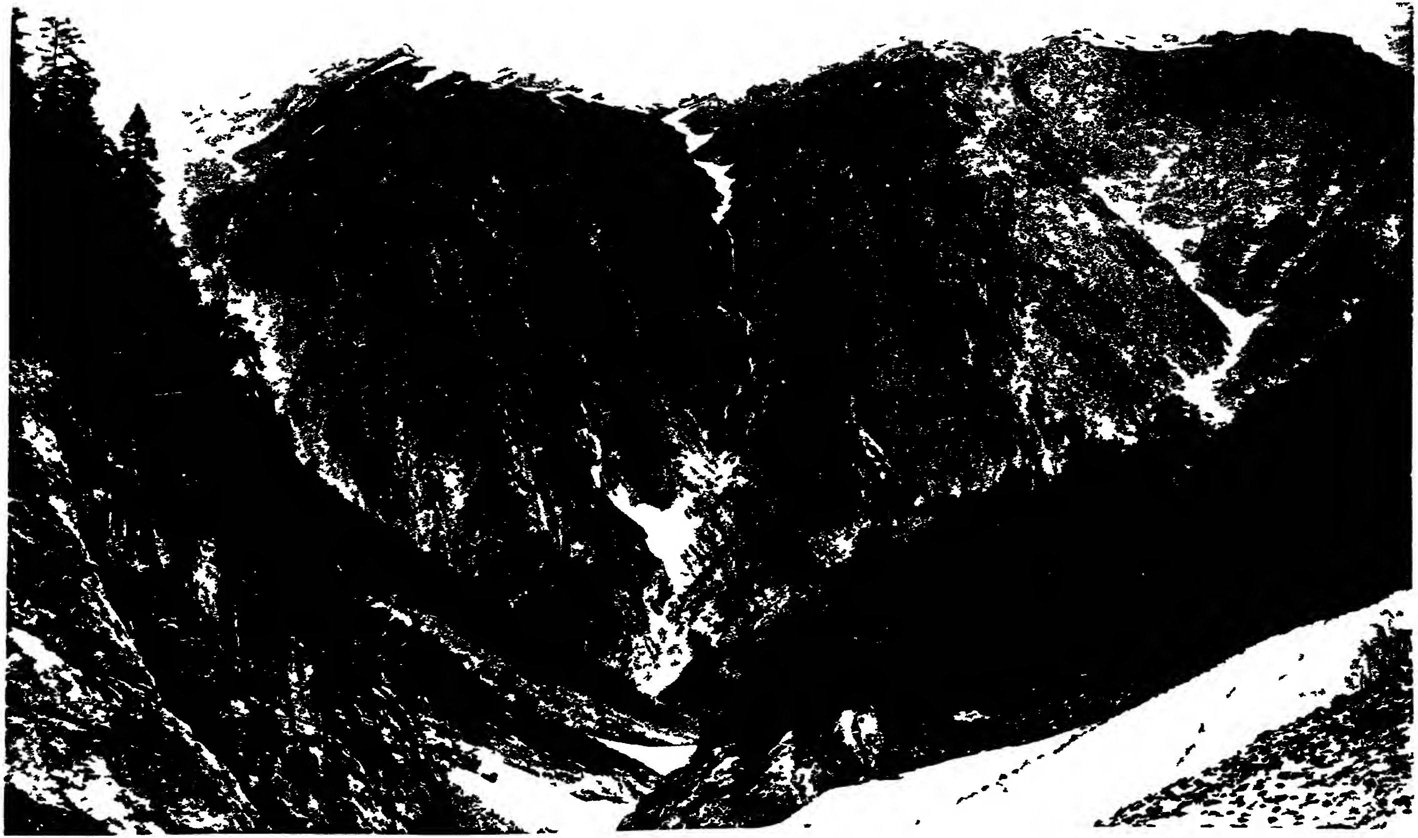
SKETCH PLAN OF THE MORAINES AT SONAMARG, SIND VALLEY, KASHMIR



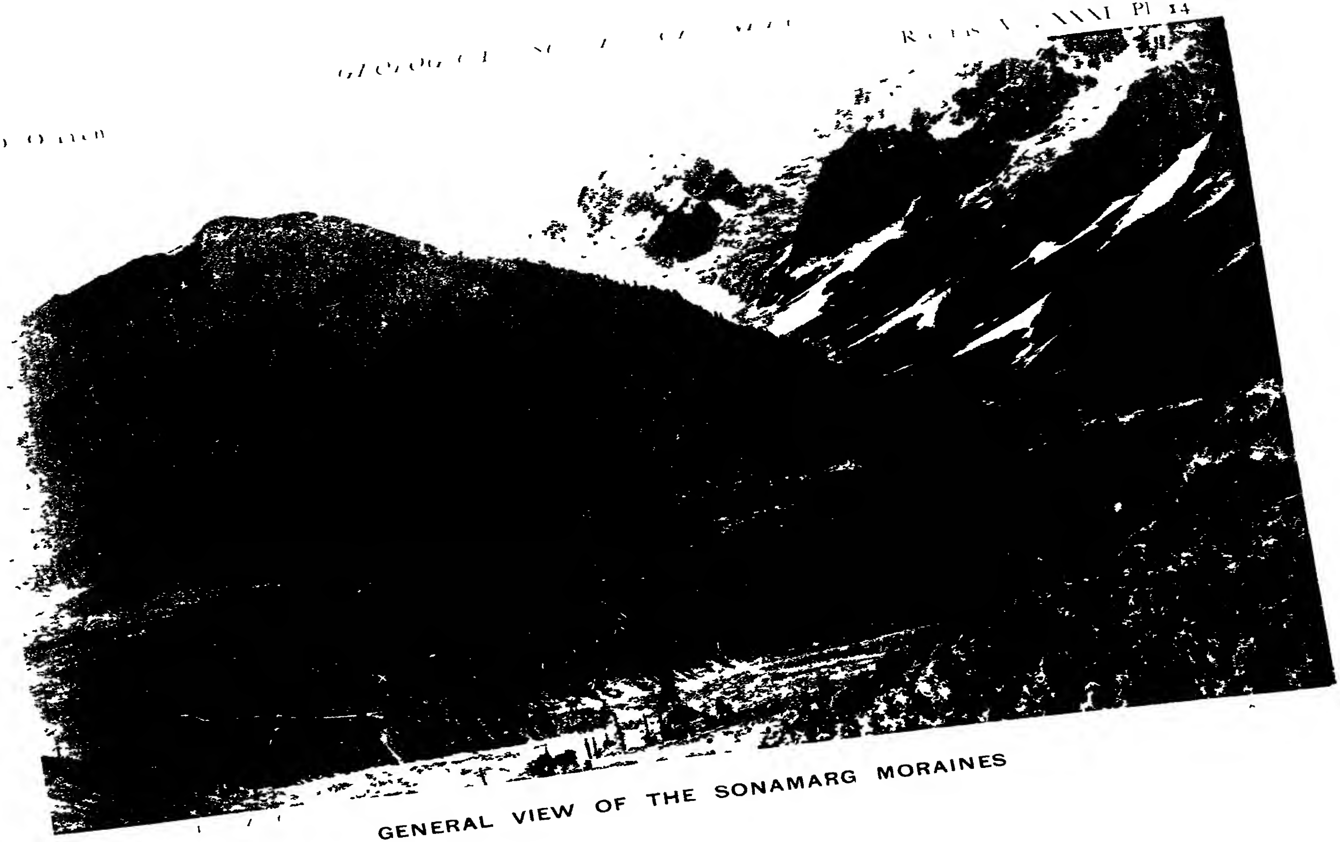
Photograph by R. D. Oldham

GORGE OF THE ZOJI LA

R D Oldham



VIEW OF THE SIND VALLEY ABOVE BALTAL



GENERAL VIEW OF THE SONAMARG MORAINES

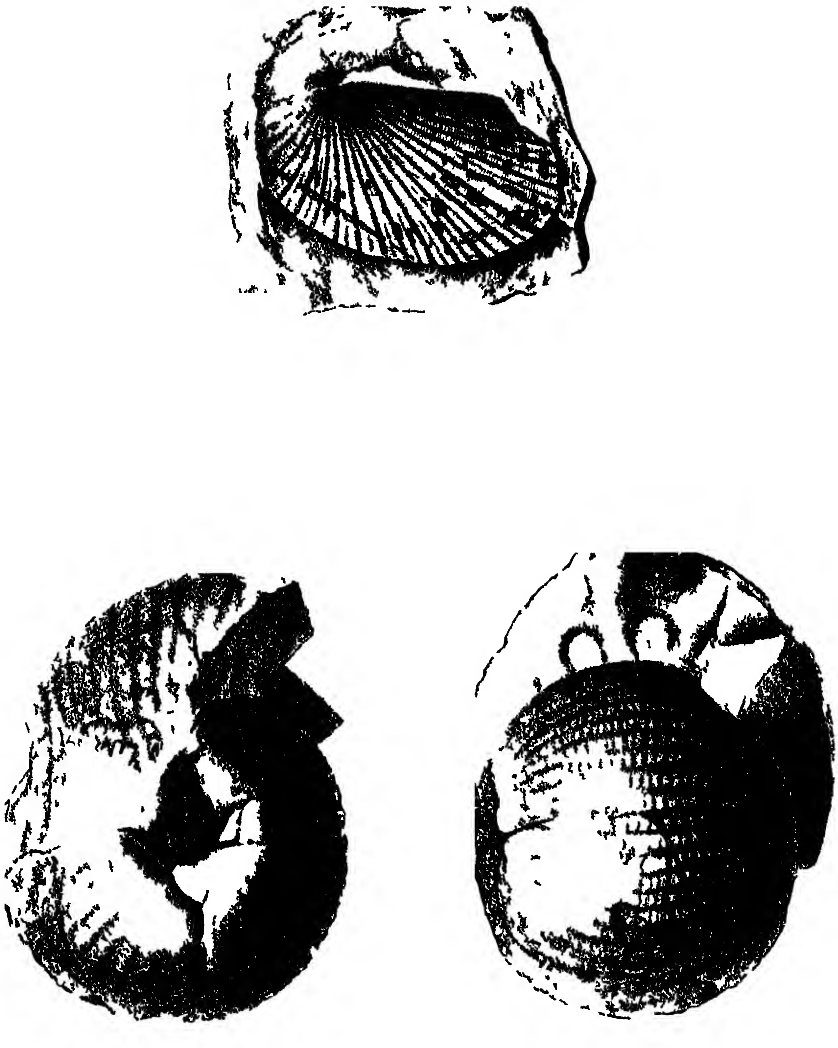
R. D. Oldham.

Photographed by R. D. O.

VIEW UP THE SHOKDAR VALLEY.

Photographed by R. D. Oldham

THE MECHOI GLACIER.



TRIASSIC FOSSILS FROM BALUCHISTAN

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1904. [October.

THE GEOLOGY OF UPPER ASSAM, *by* J. MALCOLM MACLAREN, B.Sc., F.G.S., *Mining Specialist, Geological Survey of India.*

Introduction.

The country considered in this report is that lying north of the 27th parallel of north latitude, and bounded in all other directions by the mountain ranges which wrap round the head of the Assam Valley—the Himalayas on the north-west, the Miju Ranges on the east, and the Patkai on the south-east. Except for the low spurs of the Tipam Hills, north of Jaipur, and the Manabum ridge, near the Brahmakhund, there is nothing in this area to break the level monotony of a plain that stretches down the valley with a breadth of some 60 miles, and that, though more than 500 miles from the sea, has an average elevation of about 430 feet, and a range, within the area shown on the attached map, of only from 320 to 500 feet above sea level.

The salient feature of the country is, of course, the Brahmaputra River with its great tributaries:—the Subansiri, the Dihong (the Tibetan Tsanpo), the Dibong, the Lohit or the sacred affluent of the Brahmaputra, and the Dihing. With the exception of the Subansiri and the southern branch of the Dihing, these streams converge at a point near Sadiya to form the main river. As might be expected in a region with an average annual rainfall of 115 inches, and that nearly all precipitated during seven months in the year, the country is everywhere intersected by minor waterways, the winding channels of which are in striking contrast to the direct course pursued by the main river in this portion of the valley.

Of the physical features of the hills bounding the plain it is impossible to say much. These ranges are, without exception, inhabited by wild hill tribes, whose open or covert hostility, superadded to the difficulty of obtaining transport and the natural inhospitality of the mountains, makes a journey into them a matter of great difficulty if not of actual danger. Indeed, our limited knowledge of the geology of their interior has been mainly obtained during the progress of punitive expeditions conducted against tribes far apart—the Aka Tanangs and Daphlas in the extreme west, and the Singphos in the east.

Our knowledge of even the foothills, with the exception of those lying near the Makúm and Jaipur coal-fields, is very scanty, and is derived from isolated observations at widely separated points.

It will therefore be apparent that the following sketch of the geology of the area can make no pretensions whatever to completeness, and its *raison d'être* lies merely in the fact that it will be many years before a complete geological view of these hills is obtained—probably many before our knowledge of them is materially increased. Deductions have therefore in some cases been made from the occurrence of rolled and water-worn fragments in stream beds, ordinarily a most reprehensible practice and one only adopted in this paper where direct observation has been impossible; but wherever such has been the case, the fact has been explicitly stated, and no misconception can arise under that head.

Geology.

The following table shows the formations dealt with in the course of this paper:—

Archæan, Purana	Granite, gneiss, schists, slates, and limestones. The Daling Series—quartzites and slates.
Permo-Carboniferous	Lower Productus limestones (rolled fragments).
Permo-Trias	Damuda Series—shales, coal seams, etc.
?	Disang Series—sandstones and shales.
Middle Tertiary	Coal Measures of Makúm, Jaipur, etc.
Upper Tertiary	Tipam and Sub-Himalayan sandstones.
Pleistocene	High level gravels.
Recent	River alluvium.

Metamorphic and crystalline rocks.

Rocks falling under this head are restricted to the mountain ranges, and, with one exception, to the interior and to the higher of these. They appear nowhere in the Patkai Range, which is wholly, or almost wholly, composed of tertiaries, but are largely developed in the mountains to the east, north, and north-west of the valley. Previous to the work of the present season they had been recorded *in situ* in the Daphla Hills by Colonel Godwin-Austen,[1] and doubtfully *in situ* by Mr. La Touche in the Upper Dihing Valley in the Singpho Hills,[2] and further by the latter observer in the Aka Hills at a point some 40 miles west of Godwin-Austen's traverse. La Touche's observations in the Singpho Hills indicate the presence at the head of the Dihing Valley of a strongly foliated garnetiferous hornblende schist. Judging also from the débris of the Kamlang Pani, a stream flowing into the Brahmaputra above Chonkam, it is probable that the higher points of the Dapha Bum Range, culminating in Mathaidong (Dapha Bum), 15,010 feet, are of gneiss and granite, and that an axial core of these rocks extends a considerable distance to the north-west along the strike of the flanking metamorphics.[3]

No distinctive name has as yet been assigned by geographers to the great ranges that lie transversely across the head of the Assam Valley from Dapha Bum northwards, though that to the far east between the head waters of the Irawadi and of the Brahmaputra has

[1] Jour. As. Soc. Beng., Vol. XLIV, Pt. II, p. 35.

[2] Records, Geol. Surv. India, Vol. XIX, Pt. II, 1886, p. 113.

[3] Since writing the foregoing I have met with several geological notes in the journals of Lieutenants Wilcox and Rowlatt, bearing directly on the geology of the Miju Ranges. To Wilcox, though his journeys were made as long ago as 1828-1832, we are still indebted for all our knowledge of the older rocks of these mountains. He found that, as far as he was able to penetrate (25 miles E.-N.-E. of the Khund), the rocks were metamorphic, intruded in places by syenitic and by ordinary granite (As. Res., Vol. XVII, pp. 370-386). The latter was *in situ* at the So stream. The hornblende schists and epidiorites apparently have a considerable development in the interior, for Wilcox's last geological note before commencing his return journey reads: "All the rock on our course was hornblende and greenstone."

On his expedition to the Bor-Kamti country he noted "gneiss and mica slate" on the crest of the range between the Dihing and the Dapha Pani, "syenite" beyond the Phungan Bum, and "mica slate" between the Namlang and the Irawadi (*loc. cit.* p. 448). His "mica slate" we would probably now term a schist.

been termed, by Prince Henri d'Orleans, the Zayul Range. In subse quent portions of this paper these mountains will, for purposes o brevity and précision, be termed the Miju Ranges, from the name o the powerful Mishmi tribe inhabiting the inner valleys.

At the Brahmakhund the metamorphic rocks occur *in situ.* They are here quartz schists, striking N.-W. and S.-E., and dipping N.-E at angles of 45°. The sacred pool of the Hindus is situated at the bend of the river, where the stream, after flowing from the north-eas across the strike, suddenly turns to the north-west and continues its course parallel with the strike. The pool itself is formed in a back eddy of the main basin, where the river has cut a channel across a narrow hard band of rock and has eroded a softer stratum behind thus forming a recess 40 feet wide and extending behind the tongue of hard rock for a distance of some 70 feet.

Some 6-7 miles north-west of the Khund, the same schists are exposed along the base of the hills in the bed of the Tymi stream, together with a garnet and an amphibolite-schist, the ferro-magnesian constituent of the latter occasionally occurring to the almost complete exclusion of the quartz. Still further north-west, in the Dora Pani, the last exposure of these rocks was found. Here, four or five miles from Dora Mukh, is located the famous hill of "Rukhmini pitha,"[1] about 150 feet in height, and composed of more or less pure kaolinite. The rock in the only section seen was thoroughly decomposed, and its original condition can only be guessed at. It was probably a schist composed of quartz, of a felspathoid constituent, and of a ferro-magnesian silicate, the last by decomposition furnishing chlorite. In places the original strings of quartz are prominent, but the great mass of the quartz is now scattered in small grains throughout the kaolin. The dip of these rocks is naturally not very clear, but seemed to be easterly to north-east at a medium angle.

At the Brahmakhund the rock débris in the river bed is composed of granite and hornblendic gneiss, of quartzite, forming a very large percentage of the whole, and of limestone and serpentinous boulders. The quartzite not improbably represents a portion of the Purana

[1] According to the Jogini Tantra, this hill is the remains of the marriage feast of Raja Sisopal and of Rukhmini, the daughter of a neighbouring king named Bhismak. Rukhmini, being abducted by Krishna before the conclusion of the ceremony, the whole of the viands were left uneaten and have since been consolidated into their present form.

series (the former Transition or Dharwarian of the Peninsular area), resembling in its lithological features the Shillong quartzites of the Khasi Hills to the south-west.[1] Of the source of the crystalline limestone pebbles found in the Brahmaputra, considerable information is afforded by their distribution in the various streams. Neither in the Tymi nor in the Dora are they found. In the former the débris is exclusively schistose, in the latter schistose and quartzitic. These are both streams flowing from the outer range, which rises here to an altitude of some two to three thousand feet. Turning now to those streams which have a longer course and have cut a way through the first range, we find that limestone is brought down by the Brahmaputra and by the Digaru. While the percentage carried by the former is inconsiderable, there are places in the Digaru where limestone pebbles exist to the almost complete exclusion of all others, indicating that the watershed of the latter stream is almost entirely in the limestone. The final indication of the position of the limestone belt is furnished by the complete absence of its pebbles in all the streams to the west of the Digaru. The Dibong, some of whose eastern tributaries might have been expected to reach it in that direction, from its stream bed shows no evidence of having done so, though the presence of schistose rocks indicates that the streams have reached the schists which are known to lie to the west of the limestone. It is true that one boulder of limestone was found above Bomjor in the Dibong, but it is considered almost certain that this was derived from the recent high level gravels of the Brahmaputra which, as will hereafter be shown, lie in patches along the whole length of the northern foothills. From the foregoing evidence it seems reasonable to infer that the strike of the limestone is N. W.—S. E., parallel with the schists.[2] The dip also of the strata further east is probably parallel with that of the schists at the Brahmakhund, since, as far as could

[1] Memoirs, Geol. Surv. India, Vol. VII, p. 197.

[2] The following valuable geological notes are contained in the journals of Lieutenants Wilcox and Rowlatt (As. Res., Vol. XVII (1832), p. 370, and J. A. S. B, Vol. XIV (1845), p. 482, respectively), and bear directly on the subject, furnishing indeed the exact locus of the limestone. The former says:—"The base of Thematheya" (perhaps 8 miles from the Brahmakhund) "on our right, is of the same grey carbonate of lime,...and perhaps the whole mountain." Lieutenant Rowlatt adds:—"On leaving the bed of the Tiding" (10 miles N.-N.-E. of the Brahmakhund) "the road continues over the spurs of the mountains, and for some distance passes under the perpendicular cliffs of primitive limestone, from which are visible the pendulous stalactites that are peculiar to this formation."

be judged from the moderate height reached in the hill above the Khund, the ranges to the east appear to present a much steeper slope to the north-west than in the opposite direction. There can be little doubt that these rocks are the direct continuation of the Burmese axials, for the latter to the south have precisely the same angle of dip, and their strike[1] to the north-west will carry them exactly to the point where they have been found on the Brahmaputra. Further, a continuation of this strike beyond the Khund will restrict them exactly to those limits which were above assumed from a consideration of their detritus. From geological, as well as from orographical conditions, it then follows that the true termination of the great Himalayan chain must be considered to lie along a north-west line from the Brahmakhund. Orographically, the separation from the Miju Ranges may be deduced from the fact that, while the waters of the Digaru and of the Dibong find their easiest courses to lie in a general E.—W. direction, the valley of the Brahmaputra, the only river which really breaks into the Miju Ranges, gradually turns to the north, until its headwaters flow south, parallel with the great Burmese river system, which is continued in the Salween and Mekong, far into Tibet, and to which system the short meridional portion of the valley of the Lohit Brahmaputra or Zayul may indeed at one time have belonged.

Of the granite and gneiss of these mountains, nothing definite can be said. They probably, from their resistance to denudation, form the higher ranges of 11,000 to 14,000 feet. The Miju Ranges give considerable promise of containing deposits of economic value. The schists, where seen, contained merely lenticles and stringers of quartz and no true quartz veins, but they are nevertheless the probable source of all the gold that is now so widely scattered over the Upper Assam Valley. Whilst among the Kamtis, the writer was shown several specimens of pyrite, of chalcopyrite and of galena, all from the Bor Kamti country to the east. From the two latter minerals the Bor Kamtis extract copper, and lead and silver respectively, and no *daos* are so highly prized among the natives at the head of the Assam Valley as those made from Bor Kamti iron. The locus of the argentiferous galena is certainly the crystalline limestone, and of the chalcopyrite either the less altered schists or, much more probably, the serpentinous rocks.

At the present time the only economic use made, in territory

[1] Records, Geol. Surv. India, Vol. XXVI, Pt. I, p. 28.

directly under British administration, of these older rocks is of the limestone, which in the form of boulders is collected during the cold weather from the Digaru and from the Brahmaputra, and carried to Saikhwa Ghat and to Dibrugarh to be distributed and burned for lime for agricultural and constructive purposes. None other than this so called "Sadiya lime" is used in the Dibrugarh district. It varies in colour from bluish-black to white, and is, from its completely crystalline nature, quite unfossiliferous. It seems to have been originally so pure that metamorphism has developed in it no accessory minerals, in this respect differing somewhat from the Burmese limestones, which generally contain actinolite.

On following the Himalayas along the valley to the west, little evidence of value concerning the nature of the mountain ranges was afforded by either the Dibong or the Dihong. The only difference between these rivers lies in the absence in the Dihong of the schistose débris already mentioned as occurring in the Dibong. Otherwise the deposits of both are characterised by great quantities of quartzite, white or pink, and of an amygdaloidal diabase, these two rocks, together with a fine jasperoid conglomerate, constituting quite 95 per cent. of the whole débris in the latter river. Little attention was given to the Dihong, partly from lack of opportunity, but mainly from the fact that it drains such a vast area on the northern side of the Himalayas that no deductions whatever can be made from the occurrence of a particular rock in its bed. The scarcity of granite and gneiss is, however, interesting.

Still further west, the Subansiri River affords some information concerning the nature of the hills. Here, as in the Dihong, granite is rare, and such as does occur is derived from the high level river gravel already mentioned. Gneiss of a strongly foliated type is fairly abundant, but, as before, the main mass of the detritus is composed of quartzite, both white and pink. This predominance of quartzite by no means certainly represents an equally wide distribution in the hills, but is merely due to a naturally high resistance to weathering agents. Small quantities of a slate, so schistose as to deserve the name of phyllite, represent in all probability the Daling Series of Purana rocks first described by Mallet in Sikkim[1] and by La Touche and Godwin-Austen in the papers already quoted. La Touche describes them *in situ*, some 80 miles west of the Subansiri, as nearly

[1] Memoirs, Geol. Surv. India, Vol. XI, Pt. I.

vertical micaceous slaty schists, occasionally fine-grained and fissile, striking east and west.

Godwin-Austen found them to be represented on the Dikrang River by white quartzites and micaceous schists dipping 55° S. E., with a very regular N. E.—S. W. strike.

Permo-Carboniferous.

Among the boulders heaped at the mouth of the Subansiri gorge a few fossiliferous fragments were detected A most careful search resulted in the collection of some twenty similar boulders and pebbles. These may be divided according to lithological characters as coming from two minor horizons, the boulders of one being composed of an extremely hard black marly limestone, often with the fossils more or less centrally disposed, pointing not so much to concretionary structure as to a radial hardening round the shell by outward transference of its carbonate of lime, while the second division has its fossils embedded in a much more arenaceous rock, sometimes indeed so coarse in texture that it is a matter for surprise that the fossil form should have been preserved. The principal fossils are the following :—

(*a*) In the arenaceous rock—

Productus sp.
Dielasma cf. La Touchei, Dien.
Dielasma sp.
Spirifer cf. convolutus, Phill.
Spirifer sp.
Platyschisma ? sp.

(*b*) In the marly limestone—

Productus sp.
Chonetes sp.
Nuculana subacuta, Waag.
Myalina sp.
Pleurotomaria (Mourlonia) cf. Strzeleckiana, Morris.
Bellerophon sp.
Orthoceras sp.
Fenestella sp.

These, it will be seen, have a facies distinctly Permo-Carboniferous, and are perhaps to be correlated with the Lower Productus Limestone of the Salt Range. Beds of this age have been known hitherto only from the Salt Range and more recently from Spiti,[1] and the present occurrence appears to connect these with the Chinese occurrences,[2] and possibly with the Permo-Carboniferous strata of Tenasserim [3] and of the Southern Shan States.[4]

Of the locus of the fossiliferous bed, it is impossible to say more than that it is in the basin of the Subansiri river system. It may possibly be looked for at the base of the Damuda Series at no very great distance from the Assam plain, along the probable continuation indicated by the two isolated occurrences of those rocks shown on the accompanying map; but, from our recently acquired knowledge of the extension of the younger Spiti shales along the northern flank of the gneisses and metamorphics of the Himalayas, it seems also possible that these fossils have been brought from the headwaters of the Subansiri, which, as far as our knowledge of its course goes, appears to cut through the main chain and have its sources on the edge of the Tibetan plateau. The general appearance of the boulders gives no clue to the distance they have travelled.

Permo-Trias—Damuda Series.

Rocks belonging to this period were described by Mallet,[5] in Sikkim, considerably to the west of the Assam area. There they had suffered greatly from orogenic movements, and their contained coal seams were thoroughly crushed.

On the upper waters of the Bhoroli River, which joins the Brahmaputra at Tezpur, La Touche found Damuda rocks occurring as narrow contorted bands of hard grey quartzitic sandstones interstratified with carbonaceous shales and seams of coal, the whole dipping at very high angles and generally to the south.[6]

Godwin-Austen[7] met with them on the Dikrang River further to the east, where they had a well-defined N. E.—S. W. strike and dipped indifferently at high angles (70°-75°). They were there clay shales, often carbonaceous, interstratified with dark close-grained sandstones. The carbonaceous shales occasionally pass into a crushed splintery coal.

[1] Hayden, Mem. Geol. Surv. India, Vol. XXXVI, Pt. I.
[2] Pal. Indica, Series XIII, Vol. IV, p. 168, (1891).
[3] Manual Geol. India, p. 142.
[4] Genl. Rept., Geol. Surv. India, 1899-1900, p. 139.
[5] Memoirs, Geol. Surv. India, Vol. XI., Pt. I, p. 14.
[6] Records, Geol. Surv. India, Vol. XVIII, p. 122.
[7] Jour. As. Soc. Beng., Vol. XLIV, p. 37.

Disang Series.

This is a series of sandstones and shales distinguished by Mallet[1] and occurring to the south-east and south of Jaipur. They are of considerable thickness, and dip to the east and south-east at fairly high angles. The sandstones are "grey to greenish-grey, fine-grained and rather hard, they are mostly thin-bedded, with occasional layers of grey shale, but in some parts thick and thin beds are intermixed." The shales are splintery and grey and at times contorted, and are occasionally clunchy. The whole series is unfossiliferous, and it is extremely difficult to ascribe an age to the group. They are almost certainly older than the coal measures, which they appear to underlie and with which they are in contact only along a faulted boundary. From their lithological resemblance to certain beds of Manipur, of the Arakan Yoma, and of Burma, they have been tentatively grouped by Mallet with the Arakan-Negrais. To this classification there are several objections. The Disang beds contain neither serpentinous intrusions nor indurated cherts, nor are they as highly contorted as are the rocks of the Negrais group. Moreover, quartz veins, though occurring in the Disang rocks, are not so characteristic of them as of the Negrais. On the whole, therefore, it seems probable that these beds are to be correlated with the Tertiaries, and confirmation of this assumption is afforded by a study of the geology of the Mikir Hills in the south-west, where rocks, very similar lithologically to the Disang Series, are known to overlie the Eocene nummulitics.[2]

Serpentinous boulders are far from uncommon in the Upper Dihing, and La Touche (*loc. cit. sup.*) has recorded the presence, at about a mile below the pass from the Dihing to the Irawadi, of fine-grained fissile slates. He expresses no opinion regarding the age of these, but it is probable that they represent more truly the Arakan-Negrais and the Manipur Series than do those of the Disang Series.

Coal Measures.

These are best known in the Makúm district, where the contained coal seams are being extensively worked, but they stretch for forty miles north-east and for a hundred miles south-west, being exposed only along the northern front of the Patkai Range. They consist of

[1] Memoirs, Geol. Surv. India, Vol. XII, Pt. II, p. 18.
[2] Memoirs, Geol. Surv. India, Vol. XXVIII, Pt. I, p. 91.

alternating shales, sandstones, and coal, with a few thin calcareous layers. The sandstones are generally thin-bedded, containing, more especially to the south of Margherita, nodules of clay ironstone. The shales are grey, and weather, where the conditions are favourable, to a tough, tenacious, blue clay. Near the coal seams they pass into carbonaceous shales, often showing fairly distinct impressions of dicotyledonous leaves, which give, however, no real clue to the age of the measures. At Margherita the coal appears to attain its maximum thickness, the "thick" seam now being worked averaging some 50 feet, and reaching in the Namdang section as much as 80 feet.[1] The seam is very persistent in length, the Margherita workings showing little variation in a distance of six miles. The most remote coal seams that have been noted [2] in this area are on the flanks of Maiobum in the Dihing Valley.[3] Further south-west they occur in the Namrup, and in the Namchik. Between the Tirap and the Namchik there appears to be a gap, due no doubt to the embaying of the range and the consequent denudation to the plain level of the coal measures. From the Tirap to the Namsang River, a distance of 20 miles, the measures appear to be continuous, but the great reversed fault which runs along the base of the hills, and which indeed marks their northern limit, has at the latter place either raised the seam sufficiently high to enable the Namsang stream to completely erode it down to the presumably underlying Disang series, or it lies hidden beneath the gravels of that stream. A second reversed fault to the north-west has raised and exposed the same coal measures along the north-western flank of the Tipam Hills, from whence they strike east of Jaipur to a little beyond the Disang River. Similar coal measures are brought to the surface by the same or similar faults in the hills south of Nazira and of Moriani respectively.[4]

Not the least interesting feature of these coal measures is the almost invariable association with them of petroleum oil springs, an association so marked as to force the conclusion of a genetic connection between the oil and the coal.

During the work of the present season the area of the coal

[1] G. E. Harris, Trans. Manchester Geol. Soc., Pt. XIX, Vol. XXVI, p. 572.

[2] La Touche, *loc. cit.*

[3] Wilcox (As. Res. Vol. XVII (1832), p. 420) saw, on the right bank of the Dihing above the mouth of the Dapha Pani, "thin strata of coal alternating with blue clay in the sandstone rock."

[4] Mallet, Memoirs Geol. Surv. India, Vol. XII, Pt. II.

measures has been extended by their discovery in the Manabum Range, a long spur parallel with the Noa Dihing and running out from the Miju Mishmi country into the plains as far as the Tenga Pani. This spur is best seen from the slopes of the hills above the Brahmakhund, when it appears as a long low range of even height lying along the western horizon. Owing to the fact that the work of the season was primarily devoted to the economic investigation of the auriferous deposits, little time was available for purely geological work. The range was therefore examined in one place only, at a spot about 200 yards above Tenga Mukh. The rocks obtained left no doubt of the correlation to be adopted. They were sandstones of the true Tipam type occurring with grey shales containing ill-defined leaf impressions. The brief half hour which it was possible to give to the examination of the section, covered as it is with dense jungle, gave no clue to the relations of these two members, but it seemed likely that the sandstones of the Tipam type were not in force, and that the section represents a horizon somewhat high up in the coal measures. On ascending the hill above the section great quantities of loose quartz pebbles were exposed. These may represent a conglomerate bed in the series, but are to be referred with much more probability to an old river terrace.

So far as is known, coal measures are absent from the hills to the north of the Brahmaputra. Beyond Nizamghat, at the gorge of the Dibong River, a spot was pointed out by my Chulikotta Mishmi guide who affirmed that by day a cloud of black smoke and by night flames arose from the ground at that place. From his extremely circumstantial account, and from his care in indicating the exact spot on the slope of the opposite range, it seems at least probable that he was referring to a burning coal seam, such as has altered to coke much of the outcrop coal at Margherita. Fragments of coal have been picked up in the Dibong, but no importance need be attached to the fact since the overlying sandstones, which have here a considerable development, furnish numerous stringers and nests of lignite, the finding of which has often given rise to false hopes of good coal being discovered on the "North Bank." From the neighbourhood of the Subansiri pieces of true coal were shown to the writer. The finders had an exaggerated idea of the value of their discovery, and refused to disclose the position of the main mass, further than saying that it came from the hills some considerable distance away. According to the dip of the strata in the neighbourhood, the locus of this find, if genuine and if in the coal measures, ought to be situated some two or three miles east of the Dhol.

So general, however, is the association of coal and petroleum in Upper Assam that the complete absence of "pungs," or oil springs, from the northern bank of the Brahmaputra must be accepted as strong negative evidence of the absence from the Sub-Himalayas of coal measures corresponding to those of Margherita. Coal seams of Damuda age we already know to exist there.

The general question of the age of the coal measures will be best considered after the evidence afforded by the overlying rocks has been examined.

Tipam Sandstone and Sub-Himalayan Series.

These rocks are typically developed about the low range of hills east of Jaipur, which suggested to Mallet the name adopted for this formation. They extend for many miles north and south, in the north-east rising up on the Patkai Range to nearly 7,000 feet and completely obliterating the older rocks. Like the other members of the Tertiary series along the Dihing River, they have a general dip to the heart of the main range. In their most characteristic development they are grey, or greenish-grey, speckled sandstones made up of quartz, felspar, a white mica, biotite, hornblende and chlorite, the last when abundant giving to the rock its greenish colour. They weather to dull grey boulders, and occasionally, by decomposition of the ferro-magnesian constituents, to a rusty brown. Thin bands of clays and shales—brown, green, and bluish grey—occur, but are rare. Lignite bands are not uncommon, and the formation as a whole is characterised by the abundant presence of semi-carbonised, semi-silicified wood. False bedding is everywhere apparent, the lines of bedding being often picked out on weathering by thin strings of half-inch pebbles. As a rule, coarse conglomerates are absent.

A good section of the rocks is exposed in the Janglu Pani, a small tributary of the Dihing below Margherita. Here they are composed of the typical homogeneous sandstone, with harder, more argillaceous beds at long intervals. The general dip is S. E. and S. S. E. at 40° to 60°. At the northern end of the gorge through which the Janglu has cut its way, they appear—for the section is much obscured by jungle—to lie conformably on blue clays with carbonaceous beds, which are certainly to be referred to the coal measures. Very close to the base of the sandstones is a seam of coal, which at its thickest part, and that is no more than two to three inches, appeared to be formed in the normal way. On following the seam some little distance up the nala to the Hathi Pung, it was seen that the supposed seam was in reality a coal conglomerate, being formed by an aggregation of rounded coal pebbles. Mallet [1] describes coal conglomerates that occur near the top of the Tipam beds and also in his Dihing series, but the horizon of the seam above-mentioned is very much lower, and unless there is a fault between the Hathi Pung and the gorge of the Dihing, for which assumption there is no evidence, we must conclude that it is some 2,500 feet at least below the base of the Dihing series.

Wherever seen, the coal measures appear to conformably underlie the Tipam sandstones and to merge into them by a series of gradually thickening beds of sandstone. The evidence of the above-noted coal conglomerate, however, shows conclusively that though there may have been no unconformity of stratification between the two series, there was yet an appreciable lapse of time, sufficient at least to allow for the elevation of the coal measures. It might also be inferred from the nature of the coal detritus in the Tipam beds that, geologically speaking, this interval was of no very great duration, for the coal of the coal conglomerate is generally lignitic, indicating that it was removed from the parent seam before the latter underwent those chemical changes that have added so greatly to its value.

There appears to be no very valid reason for the separation of the uppermost beds, the Dihing series of Mallet, from the Tipam sandstones. It is true that the pebbles of the Dihing beds are composed of a sandstone precisely resembling those derived from the harder and more argillaceous members of the Tipam rocks, but the similarity of the pebbles to the sandstones of the much older Disang series is equally well marked. The whole question of the separation therefore hinges on the identity of the pebbles, the beds themselves being practically conformable with the underlying strata.

On working along the sections of these rocks near the gorge of the Dihing above Jaipur, the younger rocks are found to be brought into lateral contact with, and indeed occasionally appear to underlie

[1] *Loc cit sup.*

the older beds. These and other apparent anomalies are best explained by the assumption of the presence of a series of reversed step faults such as are normal along the line of separation of an area at rest from one undergoing elevation due to tangential stress. The evidence in favour of these reversed faults has already been collated by Mallet.

The presence of rocks with lower Tipam characters in the Manabum Range, east of the Dihing River, has been mentioned. It is very probable that they extend some distance further east and wrap round the head of the Kamlang Valley, but they are certainly absent in the vicinity of the Brahmakhund and for some 25 miles to the north-west along the flank of the schists Their first appearance on the north bank of the Brahmaputra would, judging from the outlines of the hills, appear to be in the vicinity of the old deserted Ahom walled city of Bishemnagar, and they certainly have considerable development at Nizamghat at the mouth of the Dibong gorge. Here they were examined only on the left bank, about two miles above the old Nizamghat stockade. Being in the practically hostile Abor country, the time available was naturally limited and was devoted to the economic, the main, aspect of the survey, so that here, as at the Manabum Range, neither dip nor strike were satisfactorily ascertained, all the sections seen being confused by the development of cross jointing. So far as could be judged from the landslips seen on the opposite range, the sandstone area covers at least the slopes on which are situated Dombuk and Membo, the principal Abor villages in the vicinity of the plains.

The hills immediately to the west of the Dihong were not visited during the present season, but an observation made by Medlicott in 1865 [1] shows that the characteristic sandstones are strongly developed due north of Dibrugarh, and that they there dip towards the hills. In the paper quoted an interesting discovery is recorded [2] of "a fossil elephant's tooth, found by Bryan Comber, Esq., in the gorge of the Deijmoo, north of Dibrugarh." Should the discovery be truly fossil, the specimen is unique from the Eastern Sub-Himalayas, but it would be rash to postulate the existence of a Siwalik or later fossil fauna from the evidence furnished by a single fragmentary specimen from a genus that abounds in the vicinity at the present day.

[1] Memoirs, Geol. Surv. India, Vol. IV, p. 393.
[2] *Loc. cit.*, p. 436.

In the neighbourhood of the Subansiri the typical sandstones attain a considerable thickness, and rise abruptly from the plain to heights of 2,000 to 3,000 feet, showing sheer cliff faces 600 to 700 feet high. The outermost beds as seen in the Kalia Joli, the Naubhanga, and the Virgua streams, all in the vicinity of the gorge, are pebbly conglomerates 10 to 30 feet wide and dipping north-west at 60° to 70°. The pebbles are well waterworn, range up to 4 inches in diameter, and are of rocks identical with those found in the river beds at the present time. On following the strata into the hills the dip gives place so suddenly to verticality, with a complete disappearance of the conglomerates, that it is necessary to assume that the latter have been brought to their present position by a fault. The sandstones throughout the section examined maintain an even N. W.—S. E. strike, but in the vicinity of Gayamukh, some miles within the gorge, they reverse to the S. W. Here also are intercalated in the sandstones thin bands of bluish-grey shales representing swamps on the ancient river banks, indistinct remains of vegetable matter being abundant. As in the Tipam Range, the sandstones as a whole are characterised by the presence of abundant fragments of semi-carbonised, semi-silicified wood.

In the Bhoroli River the same rocks have been mapped by La Touche.[1] There they had a considerable thickness with a general N. W.—S. E. strike and a dip varying from 65° N. E. to vertical.

There can be little doubt of the contemporaneity of these Sub-Himalayan rocks and of the Tipam sandstones. The series has now been traced in a practically unbroken line round the head of the Brahmaputra, and the lithological characters of the rocks on either side of the valley are identical. West of the Bhoroli, the Sub-Himalayan sandstones are continuous as far as the classic ground of the Siwalik Hills where their age is evidently Upper Tertiary To the same period, therefore, must the Tipam sandstones be relegated. Further, since there is no evidence of a great unconformity between the Tipam rocks and the underlying coal measures, no greater age than Middle Tertiary can be assigned to the latter. This determination receives some confirmation from a consideration of the geology of the Dhunsiri Valley and the Mikir Hills, to the south-west, where a series of rocks, there little disturbed, shows a complete

[1] *Loc. cit.*

ascending section from the eocene nummulitics, through shales and coal beds equivalent apparently to the Disang group and to the coal measures respectively, to sandstones with silicified wood perhaps representing the Tipam series.[1] The only apparent objection to this classification is found in the exceptionally good quality of the coal at Makúm and Jaipur, it being far superior to that of Bengal, despite the greater age of the latter. It may, however, be shown, with some degree of probability, that this excellence is due to accelerated chemical action rather than to any great lapse of time.

Pleistocene River Terraces.

These are to be found only along the hills at the foot of the Himalayan chain and in the Upper Dihing Valley. They either have not been formed along the foot of the Patkai Range, on the left bank of the Lower Dihing, or more probably have been completely eroded in that locality. Elevated river gravels certainly do occur in this latter area, but at such an insignificant height above the present flood level as hardly to warrant the use of the term high level gravel. In the Upper Dihing Valley, though found everywhere along the course of the stream, they are yet best developed in the Dapha, the principal tributary. Here there are three terraces, 250, 160, and 140 feet in height, respectively, the surface of the highest, and therefore the oldest, being 1,000 feet above the level of the valley. The terraces are composed of the same rocks as are now found in the bed of the valley.[2]

Nothing so well developed as the above has been seen during the present season, and the best terrace section met with was that above Parghaut or Mishmighat, where the Brahmaputra leaves the foot of the hills. This terrace is only about 150 feet in height, and forms a spur running out into the valley. Good sections are exposed on two sides, on the north by the Tymi stream, and on the south-east by the main river. As will be seen from the accompanying plate a rude stratification is developed. The contained boulders are of the rocks found in the present bed of the Brahmaputra. A succession of terraces also occurs on the opposite side of the river on the way to the Brahmakhund, but is much obscured by jungle. A similar

[1] Memoirs, Geol. Surv. India, Vol. XXVIII, Pt. I, p. 91.

[2] La Touche, Records, Geol. Surv. India, Vol. XIX, Pt. II, p. 114; S. E. Peal, Jour. As. Soc. Beng., Vol. LII, Pt. II, p. 46.

terrace, due, however, not to the Brahmaputra, but to the local stream, is met with at the gorge of the Digaru, and another at Nizamghat, on the Dibong River. At the Subansiri the old terraces are not well preserved, but a remnant 100 feet high is exposed in the Virgua stream on the left bank of the Subansiri, and another as a low ridge jutting out into the plain at the head of the Dulung, a stream flowing east to the same river. At the Kakoi, beyond Kuddum, they are, on the authority of Mr. J. L. Alexander, well exposed. Hills of confused drift, 800-900 feet high, and obviously the product of the local stream, have been noted from the mouth of the Bhoroli.[1]

The exposure of these old gravels is due to an increase of the steepness of the slope of the river valley, a change which may be effected either by elevation of the head of the valley or by depression of the lower portion. In either case the result is the same—the deposits at the head of the valley are cut down until the natural slope under the conditions prevailing is reached. From the undisturbed nature of the drifts it is hardly likely that the change arose from elevation of the head of the Lohit Brahmaputra valley, and this conclusion is supported by further evidence which will be dealt with when treating of the alluvium of the valley. The superior height of the Dapha terraces in the Upper Dihing Valley, may, on the other hand, be possibly referred to the reversed faults with extensive "throw" which have been formed along the northern base of the Patkai Range in the process of mountain building.

Alluvium.

The alluvium of the Upper Assam Valley may be divided perhaps more markedly than that of any other Indian river into the two regions of *bhangar*, or higher land, and *khadar*, or low land subject to annual flooding. The former is naturally well developed at the head of the valley east of Dibrugarh, and also as a gradually narrowing fringe along the base of the hills on either side of the valley below Dibrugarh. The slope of the river beds in this area is considerable, as evidenced by the numerous rapids and by the strength of the current. This higher land, though formed in much the same way, is by no means equivalent to the *bhabar* of the Western Sub-Himalayas, and the only slope seen which might with justice

[1] Records, Geol. Surv. India, Vol. XVIII, Pt. II, p. 122.

be compared in degree to those of the north-west occurs in the bay of the hills on the right bank of the Dibong at Nizamghat. It is probable that much *bhabar* formed along the foot hills has been removed during the wanderings of the Brahmaputra over the plain, for though that river now pursues a comparatively straight course down the middle of the valley, it has in former times certainly assisted to form the terraces on the flanks of the Sub-Himalayas. There is indeed an old Assamese tradition that the Brahmaputra in ancient times flowed along the base of the hills in this area, and that its vagaries have been considerable we already know. As lately as 1821 its course at a part much nearer the sea was along the base of the Western Garo Hills, from which it is now separated by a considerable breadth of alluvium.[1]

Above Dibrugarh, therefore, the rivers are more or less confined to their banks, but below that station there is an ever increasing width completely under water during the rains. Practically the whole of the Subansiri drainage area in the plains is thus submerged, and there is at that period of the year no dry land between North Lakhimpur and Jorhat, a distance of 35 miles. The position of the high land may be fairly well picked out on a map by the distribution of tea gardens, which are of necessity situated on land not subject to flooding. Considering the silt-laden character of the Brahmaputra, and the distance, certainly 500 miles, of this portion of the valley from the delta, the low-lying nature of this area is distinctly anomalous. An explanation for this anomaly must be sought in a change of elevation of the whole or of some portion of the floor of the valley. It is clear that in the area under question the land cannot be rising, and it is equally clear that it is not stationary, for in that case, with a river carrying so much solid matter in suspension as the Brahmaputra, the level of the adjacent plain would soon reach the flood level mark and would rapidly be carried far beyond that by the abundant vegetable growth of the country. It must therefore be assumed that the floor of the valley is here sinking. For this assumption there is some evidence. Outside the area we know from the evidence of the Calcutta bore-hole that that portion of the valley has sunk many hundreds of feet. Within the area we are also able to find confirmation of the truth of the general assumption. At Pathalipam, on the Subansiri, a flood of some years ago washed away a considerable acreage of tea land, exposing, ten

[1] Geol. Trans., Series II, Vol. I, p. 132, 1824; *Ib.* II., p. 393, 1829.

to fifteen feet below the former level, the remains of an old forest with stumps of trees three feet in height, projecting from a bed of blue clay. The stumps have been identified by Mr. J. L. Alexander as belonging to the still local *bhi* (*Salix tetrasperma*), a tree of the willow family affecting swamps. It is hardly probable that any portion of land so close to the hills and to the Subansiri, and therefore subject to flooding, ever stood at that depth below the ordinary level of the adjacent river banks, and we must conclude that the swamp has been considerably depressed. Further evidence of depression appears to be furnished by the gorge of the Subansiri. This is a deep, narrow rift, 800-900 feet above water level, and in one place at least more than 360 feet (the length of a mahaseer fishing line) below it. It is four miles from the mouth to the first rapid at Gaya Mukh, and it does not appear conceivable that any river, even a Himalayan river, could excavate its bed to such a depth and for such a length, by the mere force of its current. On the assumption, however, that the excavation took place when the bed of the valley was higher, the facts at once are reconcilable with our knowledge of the erosive power of rivers. Still further confirmatory evidence of depression is afforded by the fact that the neighbouring streams in the sandstone have all cut their valleys back to an almost perpendicular cliff up to which the débris-laden valley floor slopes very gently. The evidence in favour of recent depression is thus, taken on the whole, fairly conclusive.

The Formation of the Assam Valley.

While from the extremely limited data at hand it can serve no useful purpose to indulge in lengthy speculations on the fascinating problem of the formation of the Assam Valley and its adjacent mountain ranges, there are yet several reasonable deductions to be drawn even from the scanty knowledge in our possession The main facts on which the history of the valley must be based may be briefly summarized as follows :—

(1) The presence of Upper Tertiary sandstones at a considerable height (maximum, 6,900 feet) on the Patkai Ranges, and on the foothills of the Eastern Himalayas.

(2) Their complete absence, so far as is known, from the Miju Ranges.

(3) The disturbance, general uptilting, and reversed faulting of the Tertiary rocks on each side of the valley.

(4) The horizontality of the Tertiary rocks of the Shillong plateau.

(5) The presence of crystalline and metamorphic rocks beneath the Shillong plateau, and, in places, as at Tezpur, along the floor of the Assam Valley.

Generally speaking, the Upper Assam Valley lies N. E. and S. W. between two fairly parallel mountain chains. Of these, the Eastern Himalayas are formed of a massive crystalline and metamorphic core, with a comparatively narrow southern fringe of sedimentary rocks, of which the outermost—the Sub-Himalayan sandstone—is also the youngest and the thickest. The Patkais, on the other hand, have, as an apparent core, a series, well developed in Manipur, of unfossiliferous slates and sandstones of indeterminate age, but which are possibly as young as Lower Tertiary. Over these there lies an immense deposit of Upper Tertiary sandstones. The head of the Assam Valley is closed by the crystallines and metamorphics of the Miju Ranges which lie across it at right angles to the trend of the two lateral ranges. Almost across the mouth of the valley is the Shillong plateau running obliquely from east to west and deflecting the Brahmaputra from its south-westerly to a westerly course.

The first indication of the conditions existing in this region in early Tertiary time, than which we need go no further back, is afforded by the Nummulitic limestones of the Shillong area. These are of course marine, but the thinning out observable to the north and to the east indicates an approach to the old Eocene shore line in those directions. To the east of this Nummulitic Sea was low-lying land which, at a slightly later period in geological history, was submerged and received a thick deposit of muds and clays, was again raised sufficiently high to admit of a luxuriant vegetation, and was finally depressed until its vegetation was covered by hundreds of feet of muds. These are the coal measures of Assam, and extend along the south of the valley from the Dihing River to the Shillong plateau. Of their lateral extent at the time of their formation or at the present time we are absolutely ignorant. To the north they have been truncated by the great reversed fault which runs along the south side of the Assam valley, and in the valley itself they have either been completely eroded or are buried beneath the alluvium. To the south they dip into the heart of the Patkais, and of these mountains we know no more than the outer fringe.

The muds and clays of the coal measures were, apparently without suffering intermediate denudation, now being buried beneath the enormous gravel deposits that the silt-laden rivers of the north—the ancient representatives of the Subansiri, Tsanpo, Dibong, and the Lohit Brahmaputra—were pouring in from the higher lands of what is now Tibet. These gravel beds stretched along a plain the width of Burma, from the Himalayas in the north to Prome in Pegu in the south, and must have borne a considerable resemblance to those of the present Gangetic Valley. Everywhere they are characterised by the presence of silicified wood and of lignite nests and streaks, in either case the relics of the river drift-wood. So vast a deposit points, if not to the presence of several river valleys, at least to the presence of huge tributaries, and to the probability that the drainage of all Tibet then, as now, tended to converge to a point at the head of the Assam Valley.

The eastern boundary of the ancient valley ran due south from the Miju Ranges along the flanks of the Burmese crystallines and metamorphics to nearly as far as Rangoon, with here and there an irregularity caused by the projection into the plain of older tertiaries. It would appear also that the major portion of the great land extension into the Bay of Bengal, which the Irawadi is now continuing with comparative slowness, was laid down at this time and with the spoils of the Tibetan highlands.

The western limit of deposition was, on the other hand, the sea; the coast line then running across the Shillong area to Manipur. Both in the Western Gáro Hills[1] and at Sámaguting in Manipur,[2] there have been found marine fossils of an age not differing greatly from the time of the deposition of the river gravels. The thinness and patchy nature of the Upper Tertiary sandstones of the Shillong area would indicate that this area, for a time at least, served as a land boundary to deposition.

Prior to this period the physical history of the Eastern Himalayas must be represented by a blank, relieved only by the knowledge that a restricted portion was low-lying land in Damuda time. Now, however, saw the commencement of those earth movements, the continuation of which has furnished one of the greatest of the world's mountain chains. In obedience to tangential stresses in the

[1] Geol. Trans., Series II, Vol. I, p. 132 (1824).

[2] Memoirs, Geol. Surv. India, Vol. XIX, p. 226 (1883).

earth's crust an uplift took place, at first, no doubt, general over the whole Eastern Himalayan area and unattended by any great disturbance of the strata. So much at least is indicated by the undisturbed condition of the Shillong tertiaries. With continued uplift two main, and perhaps complementary, directions of pressure become distinguishable, the one acting on the Himalayas from the north and north-west and the other on the rocks of what are now the Patkais and Aracan Ranges from the south-east and east.

It would appear that the Shillong area was soon separated by faulting from the rocks to the east. On the south of that region the strata are sharply bent over along an east and west line into a uniclinal fold, which is probably merely the expression of an extensive fault. The Shillong plateau owes its isolation and its consequent freedom from disturbance to the possession of a rigid base of crystalline and metamorphic rocks, and since there is evidence of the floor of the Assam Valley being composed of the same rocks, it is reasonable to suppose that there also a similar resistance was offered. We have considerable evidence of reversed faulting on each side of the valley, and on the foregoing assumptions the bottom of the Assam Valley may be imagined as a broad truncated wedge of immovable crystallines and metamorphics offering resistance equally to pressure in either of the abovenoted directions.

The deflection of the Brahmaputra and kindred rivers from a southerly course across Burma to a westerly one along the base of the Himalayas had taken place with the initial uplift of the Patkais and the trend of the Assam Valley was now fully determined.

Continued stress on the younger rocks found a small measure of relief in overriding the floor of the valley but a far greater in the development of earth folds. For the structure of the Himalayas and of the Patkais is not simple, as has been tacitly assumed, for example, by Suess.[1] On the other hand La Touche,[2] Godwin-Austen,[3] and Peal[4] all show that though the outermost rocks of the Himalayas dip north-west and those of the Patkais south-east, yet in either case, as the mountains are penetrated, the dip rapidly steepens and is soon

[1] La Face de la Terre, Tome I, p. 594.
[2] Records, Geol. Surv. India, Vol. XVIII, p. 122.
[3] Jour. As. Soc. Beng., Vol. XLIV, p. 37.
[4] Jour. As. Soc. Beng., Vol. XLI, Pt. I, p. 9.

reversed, and that not once, but several times. This fact disposes of an otherwise legitimate inference from the data of Suess, *viz.*, that since the opposite sides of the valley show reverse dips in similar rocks, the valley has therefore been excavated along an anticlinal axis. This inference is further negatived by the absence of the tertiary sandstones high up on the western flanks of the Miju Ranges, where, had they ever been deposited, they would certainly have escaped denudation, for the streams flowing in from that side are few, are comparatively short in course, and from their torrential character and steep fall to the Assam Valley have cut back for themselves deep gorges. So far indeed has this action proceeded in the case of the Lohit Brahmaputra, or Zayul, that it has "captured" one of the upper valleys of the Irawadi, thus breaking into the great meridional river system of Upper Burma and Tibet.

While the Brahmaputra has no doubt considerably eroded the Tertiary sandstones along its course, yet their almost complete absence from the valley surface may be due to a depression of the floor carrying down these rocks below the level of erosion and leaving no more than the Manabum Range, near the head of the valley, as evidence of their former surface extension. The protrusion of granitic rocks through the alluvium of the valley in the vicinity of Tezpur is far from clear evidence of the erosion of the Tertiaries, for it has already been shown that this area was not in the direct line of deposition, and that for some time at least it was above the valley level, bearing indeed to the Gangetic Sea on the one side and to the alluvial valley on the other much the same relation as the Arakan Yoma mountains at the present day bear to the Bay of Bengal and to the valley of the Irawadi respectively.

The already mentioned difference in height above sea-level of the river terraces at the Brahmakhund and of the Dapha Pani and the Upper Dihing cannot be accepted as altogether conclusive evidence of relative movement in comparatively recent times. The latter terraces may have been portions of extensive river flats formed near the head of the valley in much the same manner as the *patthar* above Kumki exists at the present time, and may never have formed portion of the Assam Valley alluvium as those at the Brahmakhund certainly have done.

There now remains to be considered a point of considerable interest. It will be seen on inspection of the accompanying map that, on approaching the Miju Ranges, the Patkais lose the curve that they have carried through nine degrees of latitude and turn sharply to the east and south-east. The trend of these mountains being generally an expression of the strike of their component rocks, the latter may with confidence be assumed to turn also to the east. The observed strikes in this region are scanty but seem rather to support the assumption than otherwise. On the little known northern side of the Brahmaputra a similar rapid change in the curve of the Himalayas as they approach the Miju mountains seems to take place, but in this case the deflection is towards the north.

It would appear to the writer that this phenomenon is in either case due to the same cause, *viz.*, to the retardation offered by the flanks of the immovable Miju Ranges to the horizontal movement of the plastic Tertiary rocks urged forward in obedience to the great tangential earth stresses that have formed these two mountain chains. With actual contact with the flanks of the Miju Ranges the sandstones are much disturbed and broken, as is shown by the varying strikes and dips noted by La Touche in the Upper Dihing Valley.[1] The phenomenon is indeed exactly paralleled in faulting in stratified rocks. The first indication of approach to a fault is often the gentle bending of the strata, the curve rapidly increasing with proximity to the fault, the bed finally finding relief in minor fractures along the fault line. The disturbance of the Tertiaries noted above corresponds closely with these minor dislocations. The movement of the strata in the case of the Patkais is horizontal instead of vertical, otherwise the difference is merely one of degree.

The Shillong plateau, as distinguished from the floor of fundamental rocks that are assumed to run up the Assam Valley, has exercised little retardent action on horizontal movement and has apparently in nowise influenced the direction of the Patkai Ranges. It is true that at first sight the parallel sandstones ranges of Hill Tipperah, being advanced somewhat beyond the main arc of the range, seem to be the result of an actual forward and horizontal movement due to the absence of the resistance of crystalline and metamorphic rocks immediately south of the Shillong plateau; but, if the past history of that area and the present condition of these ridges be considered, the explanation is clear. In Eocene and even in late Tertiary time a Gangetic Sea existed to the west, and there has consequently never

[1] Records, Geol. Surv. India, Vol. XIX, Pt. II, p. 114.

been any opposition to the development of normal mountain structure in that direction. Further, the Hill Tipperah ranges themselves show a decided decrease in height to the west, eminently suggestive of a decrease in intensity of stress. These advanced ridges are therefore merely the normal minor foldings in advance of a mountain chain, their absence further north being due partly to erosion, but mainly to buttressing against the older immovable rocks.

Finally, it should now be abundantly apparent that the Patkais and the Himalayas, in their later growth at least, are of contemporaneous development, and are, both orographically and geologically, entirely distinct from the great meridional mountain system of Upper Burma, Tibet, and Western China, and that, despite the assumptions of geographers who have been misled by sketchy and necessarily imperfect maps, the termination of either is practically coincident with the head of the Assam Valley.

THE AURIFEROUS OCCURRENCES OF ASSAM, *by* J. MALCOLM MACLAREN, B.Sc., F.G.S., *Mining Specialist, Geological Survey of India.*

Introduction.

From time to time during the past two decades spasmodic and invariably abortive attempts have been made to resuscitate the ancient gold industry of Assam. These attempts have generally been based on the knowledge that the rivers of Upper Assam yielded to the former Rajas, by a species of *corveé*, it is true, very large quantities of gold; and also to some extent on the knowledge that with modern dredging and hydraulicing appliances a gravel containing a very small proportion of gold can, under favourable circumstances, be made to yield profitable returns, though the same gravel might be quite unworthy of the attention of the individual washer working without the aid of extraneous power. With what prospects of financial success these projects were conceived, and the causes that have contributed to their failure, it is the object of the following to indicate.

Historical.

The first mention of the gold of Assam is contained in the Sabha Parva, the second book of the Mahabharata. Its enumeration of the gifts brought to Yudhishthira, the son of Panda, runs :—"Again in the eastern portion of the Himalayas the people on the banks of the Lauhitya river bring sandalwood, agallochum, the fragrant wood called kalyaka, skins, female slaves, curious foreign birds and beasts, and gold collected in the mountains."[1] This Lauhitya is undoubtedly the modern Brahmaputra, both the Lohits, the Chacra Lohita or greater Lohit, and the Cshudra Lohita or lesser one, being mentioned in the Matya-Purana.[2]

The famous traveller, Jean Baptiste Tavernier, writing about 1670 from information that must have been supplied to him, for he never visited Assam, says :[3] "The Kingdom of Asem is one of the best countries of all Asia, for it produces all things necessary for humane subsistence, without any need of foreign supply. There are

[1] Wilson, Ariana Antiqua, p. 135.

[2] *Vide* Wilford, Asiatic Reseatches, Vol. XIV, p. 425.

[3] Pt. II, Book III, Cap. XVI, p. 178 (1684 Ed.)

in it mines of Gold, Silver, Steel, Lead, Iron, and great store of Silk but coarse......As for their Gold they never suffer it to be transported out of the Kingdom, nor do they make any money of it, but they preserve it all in Ingots which pass in trade among the Inhabitants, but as for the Silver the King coins into money as already described."

Of the popular estimate of the wealth of Assam at that time we obtain a further glimpse from the 'Álamgírnámah of Mahomed Kazim, the historian who accompanied Mir Jumla, Aurungzebe's general, in his invasion of Assam (1660-1662):—"Gold and silver are procured here" (speaking of Lower Assam) "as in the whole country of Asam, by washing the sand of the rivers. This indeed is one of the sources of revenue. It is supposed that 12,000 and some say 20,000, are employed in the occupation; and it is a regulation that each of these persons shall pay a fixed revenue of a tola of gold to the Rajas."

In other Mussulman histories of the same period are also contained references to Assam gold. In the Padishánámah (p. 68):—"Asam......is a large country ..producing ..also gold of inferior quality which sells at half price."[1] In the Fathiyah i 'Ibriyah of Shihabuddin Talish (1662-1663)[2]:—"Gold is found in the Brahmaputra; about ten thousand people are employed in the washings. Each man on the average makes a tola of gold per annum and hands it to the Raja. But the gold is not fine and sells for 9 or 8 rupees per tola."

The auriferous deposits of Assam appear to have early attracted the attention of Europeans, for Ravenshaw, in 1833[3] mentions that 40 maunds of Brahmaputra sand that had been sent by Mr. W. Cracroft some time before, yielded a concentrate of 396 grains, of which 147·3 grains proved to be magnetite. The residue on treatment gave 1 9 grains of gold, or at the rate of 1·3 grains per ton.

The first detailed description of the state of the industry is, however contained in a paper drawn up, obviously as the result of official instructions, by one Muniram, a Revenue Sheristadar. Written in 1838, the information contained therein, being drawn mainly from the older sonwals or gold-washers, will probably truly represent the state of the industry for at least fifty years prior to the enquiry. Muniram states[4] that during the time of Raja Rajeswur Singh (1751-1768)

[1] Jour. As. Soc. Beng., Vol. XLI, p. 55.
[2] *Loc. cit.*, p. 78.
[3] Jour. As. Soc. Bengal, Vol. II, p. 266.
[4] Jour. As. Soc. Bengal, Vol. VII (1838), p. 621.

the sonwals of Upper Assam alone used to give 6,000 or 7,000 tolas (2,250 to 2,625 ounces) in addition to the *mohia* or tax that was levied on them. In Raja Gaurinath Singh's time (1780-1794) the amount contributed had fallen to 4,000 tolas (1,500 ozs.) and further still under the Bor Gohains (circa 1816) to 2,000 tolas (750 ozs.). While admitting that some trifling inaccuracies may have crept into his estimates owing to the absence of documentary evidence, Muniram reiterates that "it is a positive fact that some 4,000 tolas at the very least were annually received by the Assam Raja." The number of washers had suffered a like diminution. A careful compilation shows that while "during the time of Government"[1] (1826-1833) 457 *gotes* of *paiks*, or individuals, (a gote is a party of four) were in existence, and taxes had been paid by at least 400 gotes, these had "in the Raja's time" (Purandar Singh, 1833-1838) diminished to 184½ gotes, and even to this enumeration the *kheldars* or headmen, by whom the tax was probably directly paid, had strongly objected, affirming that there were no more than 150-160 gotes in all.

The tax paid by each sonwal was nominally half a tola of gold, but as it had to pass through many hands before being deposited in the Raja's treasury, the amount actually paid by, or rather for, each paik was as follows:—

Original tax	½ tola
Melting charges :—	
For very clean gold . . . 3 ratis per ½ tola = 1/32 tola	
For moderately clean gold . 4 ” ” ” = 1/24 ”	
For badly cleaned gold . . 6 ” ” ” = 1/16 ” .	1/16
Various perquisites :—	
Phokuns and Burias (military and civil commanders), 1 tola in 20	1/40
Teklas and Burras (peons), ½ tola in 20	1/80
Bhundar Kagoti (Phokun's writer), ¼ tola in 20 . .	1/160
Servants of the Raja's household. These were the Chung Kagoti (the Raja's treasurer), the Bhundari Likira (the assistant treasurer), the Pachoni, (chaprassi) and the Kukura Chowa Burra (orderly), and their share was at the rate of 1¼ tolas of silver for each tola of gold.	
Assuming a ratio of 20 : 1	5/160

the whole making a total of 51/80 tola of gold. The additional

[1] After the Burmese War of 1826, the province of Assam was administered for seven years by the East India Company, which then handed over government to the former Raja, Purandar Singh. Owing, however, to his incapacity, it was found necessary to resume direct administration in 1838.

27·5 per cent. thus imposed on account of taxes, etc., must under the circumstances be deemed extremely moderate, but as one column of Muniram's enumeration is devoted to those sonwal paiks who had run away and were masterless, it was probably policy rather than any feeling of compunction that restrained the exactions.

The sonwals or gold-washers appear to have contained representatives of all the classes and castes then found in Assam, but were mainly recruited from the Behiahs (a tribe of Ahoms) and from the Kacharis. With the exception of the Sadiya Kacharis, who washed under the special direction of the Raja, all other sonwals were subject to the Phokuns, Burias, or other minor chiefs under whom they happened to be dwelling.

Supplementing Muniram's paper and published at the same time were extracts from reports by Captain Hannay, who selects the Bhoroli, the Subansiri, the Desoi, and the Janglu Pani as being the most important gold-bearing streams. The gold of the last two rivers was so much prized for its colour "that the jewels of the Raja's family of Assam were invariably made up from what was collected in them."

With the resumption of direct government in 1838, the head tax on sonwals was abolished and a land revenue tax substituted. From that time onward the industry rapidly declined, the younger sonwals doubtless obtaining more easily from the fields than from the rivers the amount necessary for rent. The Government revenue from gold was obtained by farming out the annual right to wash to the highest bidder. In the year 1851, the Dihong was estimated to produce 40 to 50 tolas, and the right to wash was sold for Rs. 80. There, however, the washers were subject to the extortions of the Miris and of the wilder hill Abors, the former contenting themselves, if modern inhabitants are to be believed, with two annas' weight per tola or 12½ per cent., while nothing less than the whole satisfied the latter.

Urged no doubt by the decline in revenue from the gold washings, and probably still more by the wave of excitement that swept through the civilised world on the discovery of gold in California in 1849 and in Australia a few years later, the Government of the day, in 1853, deputed two officers—Major Hannay and Captain Dalton—both peculiarly well qualified for the work—to examine and report on the auriferous deposits of Assam. Their attention was naturally first directed to those rivers which had been famous gold producers under the Assam Rajas, and during the cold season of 1852-1853 the Janglu and Sisi streams were visited. The Janglu was even then deserted and had been so for many years. Captain Dalton was assured that the stream was the abode of evil spirits, whose good will it was necessary to obtain before commencing washing operations. As the propitiatory offerings cost more than the value of the gold obtained, the place was eventually abandoned by the native washers. Certainly the gloomy, densely-wooded and fever-haunted gorges of the Janglu at once account for the belief in evil spirits, and it is natural that in such a place the increasing poverty of the deposit should be ascribed to malignant influences.

After examining the Janglu, Major Hannay and Captain Dalton proceeded to the Sisi, flowing from the Abor hills in the north, and joining the Brahmaputra below Dibrugarh. The Sisi villagers appear to have worked the deposits in the months of January, February and March, and then only for a week or a fortnight, during which time, if they were fortunate, they might obtain sufficient to pay their revenue taxes, the result of a day's washing being occasionally 20 grains. Captain Dalton estimated the average yield from the gravel treated at 15 grains per ton, and the total yield for the season at ½ seer (15 ozs.). The whole of the Lakhimpur district in 1853 furnished 10 seers, or 300 ounces, of gold made up from the following streams[1].—Subansiri, 2 seers; Dihong, 2 seers; Brahmaputra, ¾ seer; Dihong, ¾ seer; Sisi, ½ seer; and others from ¼ to ½ seer each. The selling price of the unrefined gold was then from 14 to 15 rupees per tola,[2] the Brahmaputra gold being much lower in value than that from the northern rivers.

The explorations commenced in 1853 were continued during the following season in the Lohit Brahmaputra and in the Noa Dihing, which breaks away from the Buri Dihing at its debouchure from the hills and flows north to join the Brahmaputra above Sadiya. Traces of gold were found in the Brahmaputra as far as the Brahmakhund, but in no case were the deposits rich or extensive. Trials were made at the Guri Mara, an island in the main river opposite the Chunpura outpost. Here were washed in two days 456 maunds, or 16¾ tons, of gravel, for a total yield of 158 grains, or nearly 10 grains per ton. It appears, however, that the total amount of gravel available

[1] Jour. Roy. As. Soc., Vol. VI, p. 511.
[2] A tola = 7½ dwts. = ⅜ oz.

was limited, for, being late in the season, Captain Dalton could wash only in those places left undisturbed by the Sadiya washers. It further appears that the best seasons were those that succeeded very heavy floods, and even then a *duruni*, or washing trough, could not be expected to yield more than 2 annas weight per diem. As each duruni required at that place four men to work it, this represents a gross yield of only 8 annas worth per man per diem.

An examination of the Noa Dihing was then made, and though the extreme fineness of the gold rendered it a matter of great difficulty to treat the sands effectively, these washings are notable for having furnished a comparatively considerable quantity of platinum, and also a few grains of iridosmine, though the latter were not distinguished from the platinum until thirty years later.[1] The season's work was closed with the examination of the Dihong. At the spot there selected for trial, *viz.*, Sibia Mukh, 150 maunds or $5\frac{4}{7}$ tons gravel yielded to native washing methods 90 grains of gold, or at the rate of $16\frac{1}{8}$ grains per ton. The amount of gravel available is not stated, but was probably limited.

For many years subsequent to 1855 the annual rights of washing were submitted to auction, but the amounts offered becoming less and less the practice was at length discontinued. In 1874-5 the rights realised only Rs. 7, and in following years even less.

The decline and final disappearance of the gold-washing industry in Assam was due to a number of causes, of which the closing of the Subansiri to native washers in the interests of a proposed systematic exploitation, the poverty of the gravels, the appreciation of labour, and the extortions of the Marwari traders, or Kaiyas as they are called in Assam, appear to have been the most active. As already indicated, the old sonwals were compelled to pay their tax in gold, and in poor years each would naturally work no longer than was necessary to furnish his quota, so that the former produce of Assam must be looked on rather as a measure of the number of washers in the country than of the richness of the deposits. This assumption is confirmed by the fact that prominence is given by the early writers to the number of sonwals and not to the quantity of gold obtained by them, the latter factor being apparently regarded as bearing a fixed and definite relation to the former. Even in the days of the Assam Rajas, the number of sonwals had commenced

[1] Mallet, Records, Geol. Surv. India, Vol. XV (1882), Pt. 1, p. 53.

to decrease, probably because it was found more advantageous with the then increasing facilities for trade with European nations, to employ labour in the cultivation of the natural vegetable products of the country and to barter these for the desired gold than to obtain the same quantity of gold with greater labour from the rivers. Finally, it is certain that in the majority of cases the labour was not voluntarily given to the pursuit, for the 600—700 individuals enumerated by Muniram in 1838 had fifteen years later almost completely ceased operations. With the great appreciation of native labour attendant on the first tea "boom" of 1859-1862, gold-washing may be said to have disappeared. The sons of the old sonwals, on being questioned on the subject, invariably reply that the washings were never profitable except on the Subansiri and on the Desoi, and that they were abandoned because the younger sonwals could make more money by the cultivation of the soil coupled with occasional work on the tea gardens. On the Subansiri, which is certainly, for the native washer, the richest of all the Assamese rivers, the sonwals declare that it was only the direct prohibition of Government that compelled them to cease operations. But even there the greater part of the gold won was devoted to the payment of rent.

The method of farming out the rights to wash imposed a heavy tax on the unfortunate sonwal. These rights were generally bought for a small sum by one of the *amlah* or minor court officials, or by a hanger-on about the court, who naturally exacted as much as possible from the individual sonwal. In order to pay the rent, and to buy the quicksilver (at Rs. 3-4 per tola) necessary for his work, the sonwal, invariably the poorest of the Assamese, was forced to hypothecate to the Kaiya his whole season's output of gold, receiving no more than Rs. 8—10 per tola for what was worth in the bazar Rs. 16—17. Moreover, owing to the method of retorting the amalgam, the whole of the quicksilver employed in the process was lost, a loss certainly not less than Rs. 4—6 per tola of gold recovered.

Concessions have from time to time been granted to European speculators over various rivers in Assam, but, with the exception of the Subansiri, no serious work has been done and no great amount of capital has been expended. Attention was first directed to that river in 1884 by the publication[1] of assays crediting the gravels with

[1] *Englishman*, 2nd June, 1884, where the amount is stated in error as 26 ozs.; also Records, Geol. Surv. India, Vol. XVII, p. 192.

a value of 52 ozs. per ton, but hopes founded on these values were soon dashed to the ground by the discovery of the fact that the assays were made on concentrated sands resulting from the washing of large quantities of gravel.[1] In 1899, a company, composed mainly of tea planters, was formed with a capital of a lakh of rupees for the exploitation of the Subansiri. The operations of this company were, during three years, entirely confined to prospecting, and Rs. 70,000 were spent for no more definite result than a hazy idea that on the whole more money was necessary to prove the ground. Shortly afterwards a fairly systematic attempt, but on a small scale, was made to prove the bar at the foot of the Derpai pool above water level. In 1904 a concession was granted to a member of the original company. So far no work under this concession has been done on the ground, the energies of the concessionaire being devoted to endeavouring to float a company on the London market with a capital of four lakhs of rupees, or more than £25,000.

Native Methods of Washing.

As a general rule washing operations were formerly carried on only during the cold season, when the rivers and streams were at their lowest, but many of the Kachari washers washed during the rains when a sudden fall in the stream exposed gravels that had been subjected to the stronger currents. A spot was always selected where some concentration had taken place, as the beach below or opposite to a gravel bank in course of erosion. After preliminary trials by washing in a long bamboo scoop to determine the quantity of gold and the depth of the gravel, the overlying sands were removed either by a large wooden scraper drawn by two men and pressed down by a third, or, preferably, by damming back a portion of the stream and directing its flow over the sands to be washed away. The latter practice was invariably followed in the smaller streams. The flow of water was often continued after the gravel bed had been reached in order to concentrate the gold as much as possible before washing

[1] The explanation of this apparently high yield is the following: "Eight washers were selected, sixteen men being employed to dig and carry the gravel, supplying each washer with 400 lbs., or in all 3,200 lbs. From this about ½ lb. of concentrates were obtained yielding on treatment with quicksilver 4½ grains of gold or a little more than 3 grains per ton." It was a sample from this concentrated sand that yielded at the rate of 52 ozs. per ton. *Mining Journal*, Vol. LVII, p. 1399 (1887).

by hand. Where the gravels were exposed on the surface somewhat above the stream level, they were, to gain the same end, carried in baskets to the natural sluice made by confining the waters of the stream to a narrow channel. After a sufficient quantity of concentrated sands had been collected in the sluice, the waters were diverted to a similar parallel channel, where washing took place whilst the concentrated sands were being removed from the first channel to the washing trough or *duruni* (also termed *durani* and *dorongi*). As used at the present day, the duruni is a wooden trough 4 feet 2 inches long, 16 inches wide, and 4 inches deep, with a bottom for the most part flat, but sloping up longitudinally for the last nine inches of the upper end. The two sides are 3 inches high and ½ inch thick, but towards the lower end as they curve towards each other, they are thickened to 1½ inches. The opening left at the bottom is 2 inches wide. In the median line at the upper end is a semi-fusiform groove, 9 inches long and 1½ inches deep, into which the gold is finally worked. The wood employed in the manufacture of the washing trough is either poma (*Cedrela toona*) or makai (*Shorea Assamica*). In use the duruni is supported on three large stones, the upper end being slightly raised in order to accelerate the flow of water. The gravel which has been scraped from among the stones by means of a pointed stick and a basket (*kuki*) is sifted through a bamboo sieve (*bichana*), 18 inches wide and 24 inches long, which is placed over the upper end of the duruni. The large stones thus collected are removed from time to time by simply throwing off the *bichana*. The sand is assisted through the sieve by water poured from a bottle-shaped gourd (*lao*) held in the right hand, while the left hand is stirring up the finer sands towards the head of the trough. The vertical motion of the right hand and the horizontal reciprocating movement of the left is precisely that necessitated in the use of the Australian cradle. Stirred up by the left hand the lighter sands pass off with the water through the end opening, leaving the black sand with the gold. After washing a *shia*, or 40-50 baskets of sand, an amount probably determined by the percentage of "concentrates," the supply of sand is discontinued and the washer sets himself to collect the gold within as small a bulk as possible, working the heavier constituents always towards the head of the duruni and finally into the groove above-mentioned. This residue is then washed carefully into a copat leaf or into a bamboo knot (*chonga*). From 25-30 shias constitute a day's work, and at its conclusion the accumulated concentrates are further washed in the duruni in order to reduce the percentage of black sand as far as possible. They are then taken to the village and rubbed up by hand with quicksilver in an earthenware bowl (*soru*) until, in the language of the gold-washers, all the gold has been "eaten" by the quicksilver. Excess of quicksilver is simply removed by squeezing the amalgam in the palm of one hand by the forefinger of the other. According to Muniram, one anna weight of quicksilver for each expected tola of gold was used. This is probably incorrect and in the light of modern metallurgical knowledge would seem utterly inadequate for the purpose. At the same time the high cost of the mercury and its complete loss in the operation of retorting must have tended towards the greatest possible economy in its use. For these reasons, and also for another previously indicated, the use of mercury was not always practised. In that case the sonwal, after washing as clean as possible, separated with a little pricker of steel or of bamboo each individual grain of gold from the sands—certainly a most tedious and lengthy operation.

"Retorting," or driving off the quicksilver, is conducted in a most primitive fashion. The lump of amalgam is placed in the half of a bivalve shell, generally of a species of *Unio*, and heated in a fire of charcoal made from the wood of the nahor (*Mesua ferrea*). On the Subansiri the siah nahor (*Kayea Assamica*), a somewhat similar wood, is employed. When the shell has been reduced to lime and the quicksilver driven off, the residue is taken up on a spoon and thrown into water, the gold falling to the bottom. In former days in the case of the colour not proving satisfactory, the gold was mixed with burnt clay and salt, and reheated, a process which generally proved efficacious.

The duruni appears to have been the only washing machine employed by the Assamese sonwals. The Singphos, however, used a circular and an oval wooden tray, the latter perhaps resembling that of the Ghasis of Chota Nagpur. So universal is the disappearance of the gold-washing industry from the Assam Valley that it was only after a prolonged search and many fruitless enquiries that examples of these primitive machines were obtained—the duruni from the Subansiri River at Pathalipam, and a circular Singpho tray from Chonkam on the Tengapani River, the principal village of the Kamtis, a tribe of Shans who have been settled in the north-east corner of Assam for the last hundred years. The owner of the tray was an old and decrepid man who had abandoned his calling for nearly fifty years, and though the tray was cracked and worm-eaten, it was with the greatest difficulty that he was induced to part with this relic of his younger days. It measures two feet in diameter, and is centrically dished to a depth of 2½ inches, and is ½ inch thick. As far as could be judged from the meagre display of washing permitted by the infirmity of the old man, the method of use precisely resembled that practised in Chota Nagpur, as described in another place.[1]

Of the oval form of tray, no specimen was found, but Mr. F. J. Needham, Assistant Political Officer at Sadiya, to whom the writer is indebted for material assistance in the prosecution of his enquiries, and who has seen the gold-washings on the Hukong Valley, where similar trays are in use, says that it is deeply dished at the head for the retention of the gold and black sand, and is provided in the lower flatter portion with riffles. It does not appear that mercury was ever used with either of these trays, the washers being probably sufficiently expert in the separation of the gold from the black sand to dispense with its use.

In addition to the sands of the rivers, Muniram mentions two other sources of gold which call for some comment:—"The gold-washers in the Seedang River dry the moss and slime and then wash it in the usual manner." The Sedang River is a tributary of the Subansiri well within the hills. Considering the extremely fine character of the gold, this is at least a possible means of natural concentration, the moss acting as do the blankets in a sluice. If so, Muniram certainly omits an essential intermediate operation, *viz.*, that of burning the moss and slime to ashes before the final washing.

His third source of gold is much more problematical. "The sonwals of the Rydengia Phokun's Bhag go up to the hills and collect the *copat* which they burn for gold." The Rydengia were an Ahom tribe or *khel*, under the administration of a Phokun or chief, and the *copat* here mentioned is a species of the useful family *Zingiberaceæ*, with broad, tough and flexible green leaves, much used in Assam for wrapping purposes. Either then the story arose from the practice of burning the wrapping in which the gold dust was carried, and thus ensuring the recovery of every particle, or more probably it arose

[1] Records, Geol. Surv. India, Vol. XXXI, Pt. 2.

from the general custom of the sonwals of imparting as much mystery to their art as possible. As an example of the latter, the Miris now living on the Dihong River aver that it was the habit of the sonwals to hang cloths round their durunis and to allow no more than one Miri at a time to witness the operation of washing, declaring that the gold was so prone to taking offence that if several gazed at it, it would immediately disappear. In the territories of the stronger and more virile Abors and Miris this appeal to superstition may indeed have been adopted by the Assamese sonwals as an efficient measure of protection.

Since, so far as could be ascertained, the number of living sonwals who had formerly practised their craft is reduced to three, one at the Subansiri and two on the Desoi, their religious observances, in view of their early disappearance, are not without interest. The sonwals never commence washing operations at the beginning of the season or at an untried spot without first performing a religious ceremony. In the case of the Subansiri washer, it was necessary to supply the various materials required for the "puja." Three fowls, various articles of food, and a little whisky, in default of other spirit, sufficed. A fire was made, of necessity at the spot where washing was to be undertaken, and the old man with his two assistants sat facing it. The alcohol and food were thrown on the fire to the accompaniment of a monotonous chant, the words of which were simply "Tol Dongoria," an invocation of the name of the Deity, kindly translated for the writer by Mr. J. L. Alexander as "Under the Great One." The chant lasted about a quarter of an hour, each man meanwhile holding a fowl between his hands, with the thumbs on the back and the fingers on the breastbone. At the conclusion of the invocation the unfortunate birds were slowly squeezed to death between the hands. In former days, in addition to fowls, pigeons, ducks, and goats were sacrificed. The larger ducks and goats (which were invariably males) were sacrificed by placing their heads on a block of wood and slowly beating with a large round wooden billet. An essential feature seems to lie in the complete avoidance of bloodshed.

Not the least important part of the affair as practised before the writer appeared to be the eating of the sacrifice, the washers absolutely refusing to commence work until the ceremony had been appropriately rounded off by the consumption of the fowls.

The Desoi washers formerly practised the same ceremony, but it was never their custom to sacrifice goats—the prospective profits from that river being probably too small.

EXPLORATIONS CARRIED ON DURING THE SEASON 1903-1904.

The Buri Dihing River.

The work of the present season was commenced on the Buri Dihing, which was ascended for some 40 miles above Margherita, the head-quarters of the Assam coal industry. It was not until Mokogaon, 16 miles from Margherita, was reached, that gravels suitable for washing were met with. From thence onward these gravels occurred in rapidly increasing quantity, until the base of the hills was approached, when they were replaced by boulder beaches containing little or no gravel. Gold was invariably found in the gravels, the best prospects occurring at the mouth of the Kherim Pani flowing from the Noa Dihing, and also at Makumdong, where another stream breaks through from the Noa Dihing to the Buri Dihing. As the hills were approached the gold became less and less in quantity, until in the Namrup, above the mouth of the Namchik, the dish showed only one or two "colours" and those of the smallest. The gold, wherever found, was extremely fine and flaky, so much so that, as a general rule, quite as good a show could be obtained by washing the soil shaken from the grass roots from the top of the *chaporis*, or flood-swept islands in the river bed, as from the gravels in the river bottom. Nowhere even in the best gravels did any prospect show more than a grain to the ton, and the majority showed very much less. Similar results were obtained in the Tirap, a tributary of the Dihing. In several places and notably above Jagun, the last riverside village on the Namrup, high banks of recent river conglomerate are exposed. These on washing rarely yielded more than two or three colours. So far, therefore, as can be judged from the washings made, the gravels of the Buri Dihing hold no promise of economic importance.

The Janglu Pani.

This small stream flows from the Tipam Hills and joins the Dihing River about eight miles below Margherita. For the final four or five miles of its course it winds through a flat sandy plain covered with dense jungle. On following the stream towards its source it is found to emerge from a gorge in hills of the Tipam sandstone already described. The strata here dip S. E. to S. S. E. at angles of from 40° to 50°, and the course of the stream is at right angles to the strike, thus exposing a fairly good section of the rocks. Above the gorge, which is about 1½ miles in length, the course of the upper portion of the stream lies through a broad basin breached to the east. Two main tributaries join at the upper end of the gorge, the eastern being known, *par excellence*, as the Hone Jan—the golden stream—the western retaining the name of the Janglu Pani. A hundred yards above this junction the Hone Jan divides into three streams, at the spot known to the villagers as the Hathi Pung, a salt lick much frequented by wild animals. The Janglu Pani itself, about four miles from the junction, divides again into two main branches, which of course are again subdivided into mere rivulets as the circumscribing hills are reached. All these upper branches and tributaries flow over the flat sandy bed of the basin above mentioned.

From the foregoing it may be inferred that neither in the lower nor in the uppermost portion of the stream will gold be found—an inference borne out by the trials made.

In spite of the utterly unpromising appearance of the upper streams, it was considered necessary to make some trials there, since the Douanias of Powai Jan, the only village within five miles of the Janglu Pani, had positively asserted that all the washings had formerly been carried on at the head of the main western stream. The result proved them to be quite in error, but indeed none of the inhabitants of Powai Jan had ever seen the actual operation of washing, nor could they point out any definite spot where such had taken place, and the only real information in their possession was that the best place known to the old washers had been at a spot where three streams converged at a point, a condition found to be fulfilled at the Hathi Pung and which later operations showed to have been the only possible spot in which the old sonwals could have washed. It is a somewhat curious fact that though these villagers should have lost all knowledge of the methods and sites of washing, yet the same tradition that was told to Captain Hannay in 1838, *viz.*, that a huge lump of gold was once found by a fortunate traveller while making his way through the jungle, is still current amongst them.

It is, therefore, only in the gorge, and immediately above and below it, that the waters are sufficiently strong to carry away the overlying sands and to concentrate the heavier and larger portions of the débris into gravel beaches. These, though they carry gold in every case, in very small quantities it is true, are yet so insignificant in quantity in the lower portion of the gorge as to be quite negligible. Work was therefore concentrated on the largest patch of gravel that could be found, and this was no more than 10 cubic yards in bulk. The pebbles composing the auriferous gravel were of quartz, quartzite gneiss, a white granite, and sandstone, the last obviously of local origin. The pebbles ranged up to two inches in diameter, and of the whole it was found that only about 45 per cent. would pass through a screen of ½ inch square mesh. An attempt was made to obtain a preliminary concentration by sluicing, but it was soon found that the gold was so fine that with the grade necessary to clear the sluice box (which was of necessity somewhat short) there was a danger of losing a considerable proportion of the gold. The sluice box was therefore abandoned and concentration was effected on a shaking table of the West Australian "jigger" type. The heavy black sand left behind amounted to nearly one per cent. of the whole. So fine were these concentrates that it was found all would pass through a 40-mesh screen, and only a very small portion, and that composed mainly of rolled garnet crystals, refused to pass through a 60-mesh screen. In all the washings from the Janglu Pani and from the Dihing River a heavy white sand was left behind in the dish after all the garnets and magnetite had been removed. This on examination proved to be composed of extremely small zircons, together with a few grains of topaz.

The gravels were tried in bulk in various places to confirm the dish tests. The two following results are typical:—Gravel bars containing 10 cubic yards and 2⅝ cubic yards yielded 1·1 grains and ·4 grain, respectively, representing in either case, after allowing for the greatest possible amount lost in washing, about ⅛ grain per ton!

The quantity of gravel available is exceedingly small, certainly less than 200 cubic yards being exposed in the bed of the stream throughout its whole course. As a general rule, the deposits of gravel above the confluence of the two main streams are no more than a few cubic feet in content, and are often composed almost entirely of sandstone pebbles, a sure indication that they contain a very small quantity of gold, the latter for a reason hereafter adduced being associated with quartz and quartzite pebbles.

The hills through which the Janglu Pani flows are the normal grey and greyish-white Tipam sandstones of Mallet. At their base is a series of blue clays, occasionally highly carbonaceous, to the comparatively rapid erosion of which the basin already mentioned is due.

The source of the Janglu Pani gold was of course one of the main objects of enquiry, the scope of which was soon limited by the discovery of the almost invariable association of the gold with quartz and quartzite pebbles. On washing it was found that these pebbles were sparsely scattered in many places throughout the soil and sub-soil of the hill slopes, and further, that they were invariably associated with gold differing neither in quantity nor in quality from that found in the stream bed. This then is the proximate source of the gold. The more remote source appeared to be the thin layers of gravel intercalated with the Tipam sandstones. Probably there also occur beds of conglomerate, such as a lucky slip revealed to Captain Dalton in 1853, but these were not discovered by the present writer. Sufficient evidence of their presence is, however, afforded by the large pebbles in the stream, and perhaps by the boulders at the Hathi Pung. These last are of granite and gneiss and range up to two feet in diameter. They are unfortunately embedded just at the junction of the rock and sub-soil, and from the evidence furnished it is impossible to say whether they are erratics in the sandstone, or whether they have descended from a stratum further up the hill slope. A trial of the gravel bands, rarely more than an inch in thickness, gave a "prospect" in the dish—small indeed, but sufficient to prove that these gravel beds are competent to supply the gold found in the water-courses. The amount recovered in the dish indicated a content of much less than ½ grain per ton. It is possible also that some of the gold has been derived from Mallet's Dihing conglomerates, the beds next higher in the section to the Tipam sandstones, and it is equally possible that the degradation of a recent river terrace may have furnished some gold, but no trace could be found in the section either of such older or of more recent conglomerates.

To sum up with regard to the Janglu Pani, the amount of stream gravel available is insignificant, and the gold content is equally so, and is extremely difficult to save. The same remarks apply to the thin gravel beds *in situ*. It is therefore somewhat difficult to believe that the gold yield can ever have been extensive, or that it was indeed ever more than two or three ounces per annum, and that this supposition is correct is borne out by Captain Hannay's statement in 1838 that the sonwals considered that the time for washing was only after a rise in the river, when a fresh deposit would naturally be formed. That it was ever considered sufficiently rich to work must have been due to the great appreciation of gold in Assam. The slight concentration of gold at this point is due merely to the accident of the stream forcing its way through the low hills, thus forming a natural sluice, and is not due to the erosion or denudation of any rich deposit in the vicinity.

The Brahmaputra above Sadiya.

After the examination of the Janglu Pani the auriferous deposits of the Brahmaputra above Sadiya claimed attention. These had not been unimportant during the *regime* of the Assam Rajas, and an examination of these gravels promised to throw some light on the source of the contained gold. The Noa Dihing, which breaks away from the Buri Dihing in a manner peculiar to the Upper Assam streams on reaching the plains, was not visited. Its gold had, even by the sonwals, been considered too fine to be saved by ordinary means, and proof of this had been obtained by the writer in the washings about Bisa on the Kherim Pani, only 10 miles from the Noa Dihing and where the gold must be of the same derivation as that of the Noa Dihing. A further incentive to examine these deposits lay in the fact that it was in them that the occurrence of the rare metals—platinum, osmium, and iridium—had been determined. In face, however, of the extreme fineness of the gold, and the consequent inability to save it by modern dredging machinery, and of the probable poverty of the deposit, joined to the fact that the rainy season promised to set in early, it was considered inadvisable to spend any time in the examination of that river.

Instead of ascending the Brahmaputra to Digaru Mukh, where canoes must be abandoned for elephants or for coolies, the route selected was by way of the Tenga Pani, a minor stream which for 25 miles flows parallel and at an average distance of five miles from the great river. For the first eight to ten miles of its course, it is a deep rapid stream showing little or no gravel. Above Latau gravel banks occur more and more frequently until Chonkam is reached. From Latau to Chonkam the gravels show gold, but in very small quantities, generally far less than ½ grain gold per ton. It does not appear that the Tertiary rocks already mentioned as occurring at the Tenga Mukh have any enriching effect on the gravels, a fact that may point to the absence of the conglomerates of the Tipam sandstones from this section. Above Chonkam no appreciable increase in the value of the gravels was noted.

From Chonkam the narrow strip of intervening land was crossed to the main river which was reached at a point opposite the Digaru Mukh. Here the gravel banks gave a few, but far from encouraging "colours." Above the Digaru Mukh the Brahmaputra flows by five main channels through a wide plain. All the branches are running full during the rains, but during the cold weather the waters are confined to two or three channels, the others then showing dry stony beds, devoid, as a rule, of gravel. The route taken up the river was by the most southerly of these channels, at that time dry and forming the road for the pilgrims to the Brahmakhund. No likely spots were seen on this channel. At Parghaut or Mishmi Ghaut the river, whose waters are again united in one stream, changes its course from the east and flows from the south-east along the base of the hills. Here the current has a considerable velocity, generally far too great to admit of the deposition of gravel or of gold, though in sheltered positions small beaches were found. These yielded gold all the way to the Brahmakhund, but in very small quantities and differing nowise in character from that obtained lower down the river. A little gold was found at the Brahmakhund and in the reach above the gorge, which was as far as could be penetrated by way of the river, the Tain Mishmi hill-track to the Miju Mishmi country, towards the head waters of the Brahmaputra, leaving the river at Mishmi Ghaut and lying considerably to the north.

Opposite Mishmi Ghaut, where the pilgrim track up the dry *suti* meets the river, is the old river terrace already described. Owing to the time available for its examination being limited by the necessity for carrying all supplies in this inhospitable and almost uninhabited country, nothing further than a most cursory examination of these old gravels was possible. So far as the examination went—and it was restricted to a number of dish prospects—it failed to reveal the presence of gold. It is possible that an extended examination may show gold in a higher or lower stratum than that examined, but it is far from probable that it exists there in any quantity.

The return journey was made along the opposite or northern bank. The tributaries from this side, of which the Dora and Digaru are the principal, all yielded colours near the Brahmaputra, but failed to show anything in the dish as the hills were approached, where the larger boulders indicated the greater strength of the current during the rains. In the main river it was not until some miles below Digaru Mukh that the river bed, taken as a whole, showed gravels in which there was a reasonable hope of obtaining gold evenly distributed. The spot that appeared most favourable was the Guri Mara, a chapori or island opposite the frontier guard station of Chunpara. Above here, except in the *sutis*, or smaller branches of the river, the current was far too strong to permit of the deposition of the finer grained gravels with which the flour gold of the Brahmaputra is associated. At the Guri Mara is a high gravel bank into which the river is cutting, only to redeposit the material, with the heavier portions perhaps somewhat concentrated, on a half-mile long beach on the same side of the river. Lack of coolies and unwillingness to submit to the long delay, possibly one of weeks duration, necessary to secure these, led to nothing more than dish trials being made here. These showed only 2-3 grains per ton from the beach, and much less from the gravel bank further up the river. Captain Dalton, however, washing here in 1855 in spots pointed out to him by the native sonwals, who had not then entirely abandoned their occupation, obtained from a trial of some sixteen tons a result of nearly 10 grains per ton. It must, however, be remembered that this result, on Captain Dalton's own showing, can by no means be considered an average, for he speaks of the good wash being very limited in quantity. Indeed, most of it had been exhausted before his arrival, and we know how few must have been the number of washers practising their calling in 1855. The economic importance of the features presented at the Guri Mara will be treated later. Below the Guri Mara, gravel banks become rare and are finally replaced entirely by sand.

The Dibong River was examined only above Bomjor, and the best prospects obtained were from 14 miles higher up the stream, nearly opposite the old Nizamghat fort, and about a mile below the mouth of the gorge. This prospect showed, for Assam, fairly coarse gold, but was worth not more than 2 grains per ton. It is possible that this gold is derived from the tertiary sandstones which, as we have already seen, fringe the hills in this place. A gravel bank some two miles below the gorge and 25-30 feet in height was tried, but without result.

From Sadiya the great Dihong River, the largest of all the affluents of the Brahmaputra, was explored. Gravel first occurs about two miles from its mouth, increasing in quantity as the river is ascended. Gold in small quantities was found everywhere in the gravels until just below the Abor village of Pasighat, where for the first time in Assam a considerable residue of black sand failed to yield colours of gold. Working down the river it was found that it was only after the Dihong separates into two branches, the Lali and the Dihong, that the current had slackened sufficiently to permit of the deposition of gold. The Sibia Mukh appeared to be the most favourable spot for gold on this river, but no banks suitable for dredging were observed in the vicinity and dish "prospects" gave little encouragement to further prospecting. It is probable that much of the gold found about Sibia Mukh has been brought by the Sesseri.

The Subansiri River.

The Subansiri is the last important tributary of the Brahmaputra. So far as is known it drains an immense area of the Eastern Himalayas, but unlike the Dihong, does not break through the Tibetan tableland on the north. It has always been considered by the native washers to be one of the best rivers in Assam for their purpose, and the art of washing has lingered here longer than in any other place. Operations during the past fifty years have been confined to the area in the plains lying immediately at the foot of the ranges, but prior to that time the sonwals were accustomed to proceed to the Sedang, a large tributary of the Subansiri lying well within the hills. There the industry declined and finally ceased owing to the exactions of the hill Miris, in whose country the Sedang is situated, their demands for salt, cloths, and rice exceeding the value of the gold won. The sonwals now living on the Subansiri are of opinion that for every tola of gold to be found in that river, four may be obtained from the Sedang, an estimate probably the normal result of unattainable gold upon the imagination.

The Subansiri, owing to the recent subsidence of the valley noted in another place, does not carry its boulders nearly so far out into the plains as do the other tributaries of the main river, and the area in which gold may be found is thus restricted to only some six miles below the gorge, little gravel appearing below the Pathalipam tea garden. Even within this area it is only in suitable spots that gold may be found. These spots are the beaches left on the convex curve of a stream bank, and the bars at the lower end of a long pool.

In order to test the value of the gravel flats on either side of the river with a view to "pond dredging," the only form possible during the rains, the banks of the Derpai pool were carefully examined. These were some ten feet in height. The results obtained from dish prospects showed a very small gold content, but the matter was one of such importance that it was considered necessary to supplement the dish prospects by trials in bulk. Two lots of ten tons each were therefore washed for the insignificant yield of 2 and 1½ grains of gold, respectively, representing in either case only 1/5th grain per ton, thus completely confirming the previous trials by dish. The gold obtained was in a state of extremely fine division.

After the failure of the gravel flats, there remained only the beaches and bars of the actual river bed. The majority of these failed to give promising results, but one, at the foot of the pool and on the right bank, formerly much frequented by native washers, was pointed out by Mr. J. L. Alexander, to whom the writer is also indebted for much local information.

Here a trial was made, interrupted at times and finally terminated by floods in the river, which, owing to the abnormally wet season, was far above its usual level at that time of the year. The beach examined was often submerged, and at the lowest level experienced during the course of the trials no more than 50 square yards of the beach were uncovered. As much of this as remained above water level was collected and was at once carried above flood level. The large boulders were separated, and the remainder screened through ½ inch mesh sieves. It was found by actual measurement that the large stones, more than 3-4 inches longest diameter, constituted 54 per cent.: stones between ½ inch and 3 inches, 26 per cent.: and sand less than ½ inch, 20 per cent. of the whole. Of the large stones none were more than 18 inches longest diameter and few would reach that size. None are therefore beyond the capacity of a bucket dredge of moderate size, though stones of the largest size might cause a little delay. Of the sand nearly all will go through a much finer screen, not more than 10-15 per cent. of it being retained on a No. 6 screen. It was found by trial that 1 cubic foot of this sand weighed 93 lbs., and that therefore 1 cubic yard is roughly 1¼ tons.

Seven and a half cubic yards of this sand were washed for a return of 7½ dwts. of gold, a return, it need hardly be said, far superior to that obtained from any other part of Assam during the present season. Estimating from careful pan-tests, the heap should have yielded 10 dwts, or at the rate of 28 grains per cubic yard. The difference between the estimated and actual yield arises from the loss of gold by the machines used, and this loss occurred, not in finely divided gold, but in broad flakes thin as gold leaf, which were buoyed up by the water and carried off. On a dredge all such gold would be caught by the judicious use of mercury.

The economic aspects of this deposit will be dealt with later, for the remarks applied to it will generally apply to all the auriferous deposits of Assam of possible economic value.

Of the source of the Subansiri gold nothing very definite can be said. It is in the main certainly not derived from the old high level gravels which fringe the hills to heights of 100-150 feet, for these yielded nothing to the dish. Several of the conglomerate bands of the Sub-Himalayan sandstones were also examined, and though the great majority of the dishes gave no return, two or three showed small colours, sufficient at least to indicate these pebble bands as being the most probable source of the gold. The distribution of the gold lends some support to the assumption It is, as we have seen, found in the Sedang, the course of which lies almost certainly entirely in the sandstones. That the gold came from the older rocks which lie in the ranges north of the sandstone is negatived by the fact that nearly all the streams flowing from the first range—the Kakoi, Kuddum, and others[1]—and therefore lying wholly within the tertiary rocks, are more or less auriferous.

The Desoi River.

This river was reached late in April when the flood waters had risen so high that examination was impossible. From information

[1] The Duluni or Dulung now yields no gold, but prior to 1845 it was a favourite stream of the gold-washers. A few years before that time a huge flood had brought down immense quantities of sand and had completely buried the payable gravels (Jour. As. Soc Beng., Vol. XIV, p. 251). Much the same thing has happened in recent years in the Kakoi stream,

gathered from Mr. J. Begg, of Holunguri, and from the surviving native washers, the richest auriferous locality is the Gota Jan, a small branch of the Desoi, some eight miles within the hills, and near the junction of the Tipam sandstone and the coal measures in this place. There the conditions of concentration appear to be very similar to those noted in the Janglu Pani. The gold must also be very finely divided, for the washers expressed great astonishment on being shown the alluvial gold from the Subansiri, saying that they had never such large natural grains. The washers knew of no other auriferous streams in the vicinity, and in the Desoi itself washing was carried on only on suitable gravel banks between the Gota Jan and the Moriani Bridge, a distance of 12 miles. At no time do the washings here appear to have been either rich or numerous. As on the Subansiri, the duruni is, or rather was, the only form of machine used by the sonwals.

From the presence of the Tipam sandstones and of quartz pebbles, the latter being looked upon as an extremely favourable indication, the gold here, as elsewhere in Assam, is probably derived from the coarser pebble layers of that rock series.

Characteristics of Assam Gold.

Except in a few places on the Subansiri, the individual gold grains are extremely small and are invariably much flattened. The largest grains met with, of an extreme length of ⅛ inch, had a thickness of no more than 1/100 inch. In spite of the assertions of the old chroniclers, the gold is not of poor quality, as the following assays show. The evil reputation of Assam gold was due probably to adulteration, if any reliance may be placed in the descriptions of the Assamese character by Mussulman historians.

Samples forwarded to the Calcutta Mint by Captains Dalton and Hannay assayed as follows (Nos. 1, 2, 3),[1] and may be compared with assays (Nos. 4, 5, 6) made by the present writer :—

No.	Locality.	Gold.	Silver.	Base.
1	Brahmaputra River . . .	88·281	...	...
2	Noa Dihing " . . .	93·880	...	...
3	Dihong " . . .	90·588	...	...
4	Subansiri " . . .	89·850	9·240	0·91
5	Ditto " . . .	89·320	9·680	1·00
6	Janglu Pani " . . .	92·950	5·580	1·47

[1] Memoirs, Geol. Surv. India, Vol I, p. 93.

General.

Perhaps the most striking feature presented during the examination of the auriferous deposits of this valley is the universal distribution of the gold in extremely small percentages throughout the gravels of the river beds. This wide distribution is held to be due to two main causes—to the wandering of the Brahmaputra over the plain, and to the wide distribution of the Tipam or Sub-Himalayan sandstones, for these last are certainly auriferous in places.

Since it would appear that these sandstones were deposited by a river system not greatly dissimilar in direction from that at present in existence, it may be conjectured that their contained gold has been derived from the same source as that gold which is now being brought through the Brahmakhund with every flood, *viz.*, the quartz veins of the metamorphic and gneissic schists of the Miju Ranges. It is true that, where seen, these schists contained no well-defined quartz veins, but quartz veins will in all probability be better developed in the immediate neighbourhood of the intrusive igneous rocks, the débris of which is seen strewn in the stream beds.

From the presence of gold higher up the Assam valley than the entrance into it of the Dihong, and from the complete absence of all references to gold washings along the Tibetan Tsanpo, it is extremely improbable that the Tibetan plateau has furnished any of the gold of the Assam valley.

The next characteristic feature to be noted is the general aggregation of the gold at a point, the distance of which from the hills is dependent on the strength of the current and on the form of the gold dust. Above this point the only deposition is that which arises from local diminutions in the velocity of the current, as on the beaches at the end of a long pool, or on the beaches lying parallel with the stream and to which the gold is carried by the back-eddies, where it is retained in the interstices between the large boulders. This point of general deposition is marked on the Assam rivers by the occurrence of gravels containing pebbles up to 6 inches in diameter. Below this point are the fine-grained homogeneous river sands which contain no gold. From the foregoing it therefore follows that :—(*a*) the general search for gold must be confined to those portions of the rivers containing boulders and gravels, and (*b*) particular search must be made at the bars at the end of long pools especially where a high bank is being eroded, and also in the longitudinal boulder beaches.

To turn now to the economic consideration of the only deposits considered by the writer to be worthy of further prospecting. These spots are the Guri Mara, above Sadiya and opposite the Chunpara stockade; the Sibia Mukh on the Dihong River; and the Derpai pool of the Subansiri River. From causes already indicated, the gravels on the first two were not examined closely, but it requires no greater expenditure than that of Rs. 100—150 to determine in each case whether the deposit is valueless or whether it is sufficiently rich and extensive to justify a further expenditure of some Rs. 2,000—4,000 in determining its value as a dredging proposition. Special attention should be directed to any gravel banks in the vicinity, in the hope that these should prove sufficiently rich to enable dredging work to be carried on during the rains, with a consequent increase of profit during the cold weather when the dredge is working on the presumably richer beaches of the stream beds.

The most promising deposit is, however, that on the Subansiri. Its advantages may be tabulated as follows:—

(1) The portion exposed contains a payable proportion of gold.

(2) The nature of the gravels offers no serious hindrance to successful dredging.

(3) On a properly designed dredge there should be very little loss in gold.

On the other hand, the adverse points are:—

(1) Dredging can only be carried on for four and a half months in the year.

(2) The extent and depth of the deposit are unknown.

(3) While it is certain that a fresh supply of gold is brought to the bars and beaches every year, it is by no means so certain that, after being dredged for one season, the replenishment of the succeeding rainy season will bring the value up to that of the preceding year.

Before this can be considered to contain the elements of a successful dredging proposition, these adverse factors must be provided for or eliminated. The first is due to the fact that, in spite of all trials, it seems quite clear that the alluvial flats on either side of the river do not contain sufficient values to justify dredging, which must therefore be confined during the cold weather to the river beds. The earliest possible month in which dredging might be commenced is October, and with good fortune, the river may remain sufficiently low until the end of April, but no more than the above-mentioned lapse of time may be safely assumed.

The second point to be settled is the lateral extent and the depth of the auriferous deposit on the Derpai bar. Should it extend far below the water, and should the gold be evenly distributed throughout a considerable depth of gravel, the proposition must certainly be considered eminently payable. This crucial examination presents no great difficulty and would indeed have been performed by the writer during the present season, had it not been for the abnormally early rains, the consequent river floods, and the impossibility of procuring before the close of the season the necessary apparatus for the purpose, all joined to the fact that, since these auriferous deposits are now occupying the attention of private persons, the work is one that may reasonably be left to private enterprise.

The deposits lying in the bed of the river, examination by shafts is out of the question. The use of drilling machinery of the ordinary Keystone type is prohibited by the presence of the large boulders already noted. To the writer, the best and most efficacious method would appear to lie in the use of a hand-power double chain grab, of the Priestman type, and of a capacity of 3-4 cubic feet, and made as watertight as possible. The grab should first be set to work on the bar above water-level, and the depth of the gravel proved at that place, the gravels being transferred to suitable screening and washing machines to determine the values at successive depths. For proving the lateral extent of the deposit beneath the water-level, the derrick should be placed on a pontoon made on the spot from country boats. Skilfully handled, the grab should even under water make a fairly vertical shaft in the gravels. From the pontoon the gravel should be carried to washing machines on the bank and its gold content there ascertained. The actual cost of such prospecting should be no more than Rs. 2,500—3,000, and this initial prospecting is absolutely imperative before any dredging machine capable of dealing with large quantities of gravel is placed on the river. To form a company with a large capital, and to expend money on a dredge before these preliminary details are settled, is merely courting disaster, and from a commercial point of view—the only one which can be taken with regard to these enterprises—is absolutely inexcusable. For success in gold dredging, unlike in most other forms of gold mining, is not a matter of happy chance, but results from the careful calculation of bulk, value, and expenses—factors which are procurable with comparative ease and cheapness.

Further, as already pointed out, there is a possibility of decrease in value of the bars reformed after dredging. This is a matter which nothing short of actual trial can settle, but it is at the same time one of considerable importance, since the number of dredgable bars is extremely limited, and none examined by the writer approached in any degree the richness of that at the foot of the Derpai pool.

From the foregoing it follows that even if, on further trial, all the conditions appear to be favourable, a company with a limited capital —certainly not more than a lakh of rupees (or say £6,500)—will command the most chances of success, or rather, what is not quite the same thing, the fewest chances of failure. Overcapitalization and the erection of huge plant to deal with unknown conditions will in this, as in any other form of commercial experiment, inevitably spell failure.

The gold on a properly designed dredge should be easily saved. Efficient screening, the size of the smallest mesh being regulated by the maximum breadth of the gold grains,—in the case of the Derpai gold, the largest grains being $\frac{1}{8}$ inch broad, a No. 6 screen—is the first essential. The load of sand on the washing tables is thus reduced to the minimum. Sufficient breadth must be given to the tables to admit of a thin even flow of pulp, so thin that every gold grain may be enabled to come in contact with the canvas or burlap or whatever is used on the tables. Plush, owing to the large percentage of garnet and heavy black sand, will probably be found to choke very easily. To enable the finer leaf gold to be saved, it will be advisable to supplement the canvas tables with amalgamated copper plates.

Despite the above, and despite the fact that owing to the great extent of country covered the majority of the auriferous deposits received no more than the most superficial examination, and many must have been entirely overlooked, the general impression left on the writer's mind as to the potential value of the Assam gold deposits is distinctly unfavourable. Here, as in most other parts of India, the climatic conditions that make for concentration of gold have always been absent. There has never been that even flow of waters confined within well-marked banks, that, continued throughout centuries, finally results in a general separation and a local concentration according to specific gravity of the river-borne minerals in "leads" and "runs." On the other hand, there have been annual floods, varying so quickly in height, velocity, and direction, that the slight local concentration of one year has been inevitably neutralised during the floods of the succeeding rainy season.

Judging from the great difficulty experienced in locating the exact spots on the various rivers where the richest gold was obtained in former days, it would appear that no good purpose has been served by prohibiting the surviving sonwals from washing. It has indeed been a matter of great hardship to these men, who knew but the one craft, and who, for long, until they finally decided to devote themselves entirely to the less attractive tillage of the soil, were on the verge of starvation. The surviving sonwals—there are but three—expressed the greatest desire to resume work, not so much now for their own sake, as to teach the younger men the art, and to provide them with an additional means of livelihood. They state that nothing but the direct prohibition on the Subansiri and the fear of a heavy royalty on the Desoi have prevented them from working. On the Subansiri they were prohibited in the interests of larger enterprises, but this 35 years of indirect encouragement to capital has been productive of no useful result. Indeed, in those very interests it is most desirable that the younger sonwals should be induced to practise their ancestral calling, thus ensuring a knowledge of the richest gravel-banks—a knowledge that we do not now possess.

Moreover, whatever may be true of the river bars below water-level, it is certainly true that the gold of the beaches formerly frequented by the sonwals was renewed from year to year. Even on an ordinary concession their few cubic yards and their few tolas of gold could make but little difference in the gross yield of a dredge, one single revolution of whose buckets will raise more gravel than 15 sonwals can wash in a day.

ON A CURIOUS OCCURRENCE OF SCAPOLITE FROM THE MADRAS PRESIDENCY, *by* E. VREDENBURG, A.R.C.S., *Deputy Superintendent, Geological Survey of India.* (With Plate 29.)

The specimen of which an illustration is herewith published belongs to the Madras Museum, where it is now exhibited. It was sent to the Geological Survey of India by Mr. Edgar Thurston, Superintendent of the Government Museum, Madras, for determination of the curious star-like aggregates of lath-shaped white crystals that occupy one of its faces.

The specimen is said to have been obtained from "a trap dyke in the Godavari district." It is a large, irregular, naturally-weathered block, weighing 66 lbs., with no signs of artificial fracture. It consists mainly of a fine-grained, regular-textured, holocrystalline, basic rock, of specific gravity 3·10, made up of augite, hornblende, and felspar. The augite forms brown translucent grains nearly colourless in a microscopic section. The hornblende grains are black, and, in section, appear dark-brown and strongly pleochroic. The white felspar is a basic plagioclase. The structure is thoroughly granular, without any tendency to development of distinct crystalline shapes.

One face of the large block is flat or slightly concave and is covered with a black film, in the midst of which are the star-like clusters of white crystals shown in the illustration.[1] This black film is scarcely five millimetres thick, and the white, lath-shaped crystals are still thinner, although measuring as much as a centimetre in width. The black mineral of the film is the same hornblende as that of the main rock with which it is in continuity. The mineral forming the broad prismatic crystals is scapolite, showing a striated structure parallel to the direction of the vertical axis. But this mineral does not constitute the entire substance of the white prisms, for the scapolite is surrounded by a very thin shell of basic felspar.

[1] In the illustration, the black portion of the film looks as if suffused with white specks. The large prisms are, however, the only white portions of that particular surface, and the appearance of small white patches is due to the irregular reflection of light upon the cleavage planes of the black hornblende grains.

In the absence of any definite information regarding the mode of occurrence of the rock, there remains some doubt as to the true nature of the film: it may represent the contact between two rock masses of different composition, or it may be a narrow vein filling a 'fissure' through the homogeneous felspar-pyroxene-amphibole rock. Considering the identity of the hornblende of the film with that of the main mass of the rock, the latter explanation appears to be the more probable. The film would then be a contemporaneous vein, that is, a fissure filled-in, before the complete cooling of the rock, by the residual magma, and of about the same bulk composition as the rock itself, for, although the ferro-magnesian and the lime-alumina silicates are distributed differently in the film and in the main mass, their relative amounts cannot much differ in either instance. As scapolite chemically differs from plagioclase mainly in the introduction of chlorine, the alteration in mineralogical composition is presumably due to the action of chlorine vapours passing along the fissure during the cooling of the rock-mass.

MISCELLANEOUS NOTES.

A new form of blue Amphibole from Central India.

An extremely interesting rock, found by Mr. Howard J. Winch, was brought to the Geological Survey Office by Mr. H. Kilburn Scott. The rock, which was found near the deposit of manganese ore at Meghnagar on the Godhra-Ratlam Railway, is of a blue colour with a lavender tinge, and to the naked eye is a schist composed of prisms of blue amphibole, averaging a quarter of an inch long, with an interstitial black mineral. This black mineral is a manganese oxide, while the amphibole is also slightly manganiferous, but in the latter case the manganese reaction obtained may be partly due to a little of the black oxide, which the amphibole usually contains, not having been completely separated, though it was attempted to remove it entirely by the use of Sonstadt's solution. This amphibole also gives a strong flame-reaction for sodium.

Microscopically the rock is seen to be composed of the amphibole with its characteristic prism-angles and interstitial quartz, calcite and a large amount of the black manganese mineral included in all the other three. As the amphibole often shows black cloudings in its interior, probably of secondary origin, besides the original black mineral, it is in all likelihood a manganese amphibole. Its scheme of pleochroism is:—

$\mathfrak{a}$ = pinkish lilac.
$\mathfrak{b}$ = paler lilac.
$\mathfrak{c}$ = blue.

By polarized light it is seen that the mineral shows irregular zoning, due probably to varying composition. As the inner zone seems to have the presumed manganese-ore dust developed in it more readily than the outer shell, it seems probable that there is a gradual change from the most basic composition inside to the most acid outside. This change in composition is accompanied by a change in position of the elasticity axes. For the basic portions of the amphibole the elasticity axis $\mathfrak{a}$ is the one nearest to the vertical crystallographic axis, c'. The angle $\mathfrak{a}\wedge c'$ may be as low as 16°, but as one passes from the interior, most basic, portion to the outer, most acid, portion in a zoned individual, the axis $\mathfrak{a}$ gradually swings away from the vertical crystallographic axis c' till it makes an angle sometimes as large as 70° with c'. The elasticity axis $\mathfrak{c}$ has of course now rotated into proximity with the crystallographic axis c', making with it an angle of 20°; so that $c \wedge c' = 20°$.

As will be seen from the pleochroism scheme, this rotation of the elasticity axes is accompanied by a change from lilac to blue, as the elasticity axis nearest the vertical crystallographic axis changes from a to c; consequently these compound crystals do not show even colouring, but are in irregular patches of blue and lilac. Though some of the crystals in the microscope slide are almost entirely of one composition, either acid or basic, it is easy to distinguish them at once by the colour corresponding to the elasticity axis nearest c', thus:—

Chemical character.	Axis nearest c', is	Corresponding colour.
Basic	a	Pinkish lilac.
Acid	c	Blue.

The polarization colours of this amphibole are very low, rarely rising above the first order. The sign and other optical properties cannot be determined until some better material has been obtained.

The specific gravity of the rock determined from the mean of two small pieces, is 2·88, while that of a small crystal of amphibole was 2·86, though this latter will necessarily vary with the varying composition of the mineral, as well as with the amount of the black manganese mineral included.

Of the known amphiboles, the one under discussion approaches most nearly, as regards its pleochroism scheme, to the soda-amphibole glaucophane; but even from this it is decidedly different, for the a axis colour of glaucophane is given as yellowish green to colourless instead of pinkish lilac. The present mineral differs completely, however, from the soda-amphiboles in having a much smaller specific gravity. Also the angle $a \wedge c'$, instead of being 4°—6° as in glaucophane or riebeckite, or 14° as for arfvedsonite, or the 18°—20° of crocidolite, can vary between 16° and 70°. Considering that no other amphiboles are known showing anything like the pleochroism of the present mineral, it is almost certain that we have here a new species of amphibole, characterised by great variation in composition, producing corresponding variations in its optical properties, and it is hoped that an early opportunity will occur for collecting material sufficient for a more complete investigation of the properties of the mineral.

[L. L. FERMOR.]

An unusual occurrence of Common Salt.

The manganese-ore at Kándri mine near Rámtek, in the Nágpúr district of the Central Provinces, is characterized by extremely well developed slickensiding, which separates the ore into huge striated columns dipping to the E. 25° S. at 25°—30°. In level No 1 a good section across the ore body and country rock has been exposed, and the north-east wall of the deposit is seen to be a fine-grained, greyish and pinkish, schistose, felspathic and micaceous quartzite, which is seen microscopically to contain, besides the quartz, a fair quantity of microcline and white mica with a little magnetite. This rock partakes of the same slickensiding as the manganese-ore, and in common with the latter is divided by joint-planes at right angles to the slickensiding, producing the above-mentioned columns. The cross-joint planes of these quartzite columns were marked in places with black dendrites, doubtless of oxide of manganese, and in other parts had a white saline coating up to a quarter of an inch thick, really composed of fine white needles. Some of this white substance was scraped off, tested in the laboratory, and found to be essentially sodium chloride. As extraneous matter had been included with the salt, Rám Chandran, M.A., separated off 40·3 per cent. of material insoluble in hot water, and found that the solution contained, besides the sodium chloride, also a little calcium, magnesium, and a trace of potassium, with a little sulphuric acid, of course, as sulphate.

Hence, the fine white felt is almost entirely sodium chloride, introduced presumably by percolation of meteoric water, and subsequent concentration by evaporation.

[L. L. FERMOR.]

Assays of Coal and Coke from the Jherria and Ráníganj fields.

The following assays of coal and coke from the Jherria and Ráníganj fields have been made on samples selected under the superintendence of Mr. E. P. Martin and Professor H. Louis, and are now published, with the consent of the coal companies concerned, through the courtesy of the Right Honourable Sir E. Cassel, for whom the assays have been made. All the coal samples have been uniformly sampled across the working face of the seams, and they consequently are not open to the usual objection made against samples which are picked from a pile, or from a particular part of a seam.

The beds in which the coal is now being mined in the Jherria field were long ago correlated by the Geological Survey with the Barákar series of the

Raniganj coal-field (Hughes, *Mem. Geol. Surv. Ind.*, V., p. 231, 1866), and it is interesting to notice that the low percentage of moisture, noticed by Dr. W. Saise in the coal of the Barákar series in the Ràniganj field (vide *Records Geol. Surv. Ind.*, vol. XXXI, p. 104), is characteristic also of the Barákar coal in the Jherria field. In the case of the Barákar coal from the Ràniganj field the moisture amounted on an average to 1·00 per cent., whilst in the case of these Jherria coals the average for moisture is 0·90 per cent.

[T. H. HOLLAND.]

COALS FROM THE JHERRIA FIELD.

Seam.	COLLIERY.	Fixed Carbon.	Volatile Matter.	S.	Ash.	Moisture.	Lbs. of water evaporated by 1 lb. coal.	REMARKS.
		%	%	%	%	%		
17	Jamadhoba and Jorapukhar.	59·76	26·54	0·51	11·77	1·40	12·91	Contains 0·098 per cent. phosphorus.
15	Bhaga (coal) . .	62·87	24·71	0·37	11·05	1·00	13·10	
15	Do. (band) . .	53·97	26·42	0·36	18·35	0·90	11·71	
15	Loyabad . . .	60·92	21·90	0·56	15·70	0·92	13·26	Contains 0·197 per cent. phosphorus.
15	Kankanee . .	67·82	21·02	...	10·38	0·78	...	
15	Katras . . .	68·69	19·99	...	10·71	0·61	...	
14	Kankanee . .	71·54	17·28	...	10·52	0·66	...	
14	Jogta . . .	68·51	19·04	0·53	10·92	1·00	13·61	
14	Do. . . .	69·75	19·79	...	10·05	0·41	...	
14	Katras . . .	55·80	20·01	0·56	22·57	1·06	12·27	Contains 0·146 per cent. phosphorus.
13	Alkoosa . . .	61·62	21·23	0·62	15·57	0·96	12·87	Contains 0·258 per cent. phosphorus.
13	Katras . . .	63·75	18·78	0·55	15·72	1·20	12·60	
12	Do. . . .	55·93	22·02	0·63	20·50	0·92	12·47	
12	Alkoosa (band) .	58·79	19·86	0·62	19·85	0·88	12·71	
12	Do. (coal) . .	62·28	21·65	0·73	14·20	1·14	13·16	
11	Do. . . .	57·39	19·56	0·62	21·75	0·68	11·96	
A	Bhowra . . .	65·99	26·22	...	7·01	0·78	...	

COALS FROM THE RANIGANJ FIELD.

Seam.	Colliery.	Fixed Carbon.	Volatile Hydro-carbons.	S.	Ash.	Moisture.	Lbs. of water evaporated by 1 lb. coal.
		%	%	%	%	%	
Gourangdi .	Gourangdi . .	51·76	26·99	0·68	19·45	1·12	12·51
Deshergarh .	Panchgachia . .	51·01	31·32	0·67	14·70	2·30	12·52
Do. .	Sanctoria and Sodepur.	52·80	33·60	0·30	11·70	1·60	13·36
Sanctoria .	Sanctoria . .	53·68	33·80	0·25	10·55	1·72	13·16

COKES MADE FROM JHERRIA COAL.

No. of Coal-Seam.	Colliery.	C.	S.	P.	Ash.	Moisture.
		%	%	%	%	%
15	Loyabad . . .	73·91	0·50	0·23	23·91	1·45
15	Do. . . .	76·48	0·53	0·29	21·58	1·12
15	Kankanee . . .	79·67	0·73	0·17	18·98	0·45
15	Katras	77·03	0·60	0·09	31·99	0·29
14	Kankanee . . .	76·97	0·77	0·20	22·00	0·06
14	Katras . . .	71·02	0·67	0·32	27·76	0·23
13	Do. . . .	76·30	0·62	0·06	22·80	0·28
13	Do. . .	64·22	0·65	0·03	34·97	0·13
A	Bhowra . . .	80·91	0·85	0·14	17·79	0·31

G. I. C. P. O.—No. 565 D. G. S.—26-11-04.—600.—J. J. MARUM.

INDEX TO VOLUME XXXI.

N

O

T

RUKHMINI PITHA HILL DOPA PANI ASSAM

HIGH LEVEL GRAVEL, MISHMI GHAT, ASSAM

SUBANSIRI GORGE ASSAM

(Fig. 1.)

NATIVE WASHER AND ASSISTANT.

J. M. Mac..., Photo. (Fig. 2.) *Bemrose, Collo., Derby, Eng.*

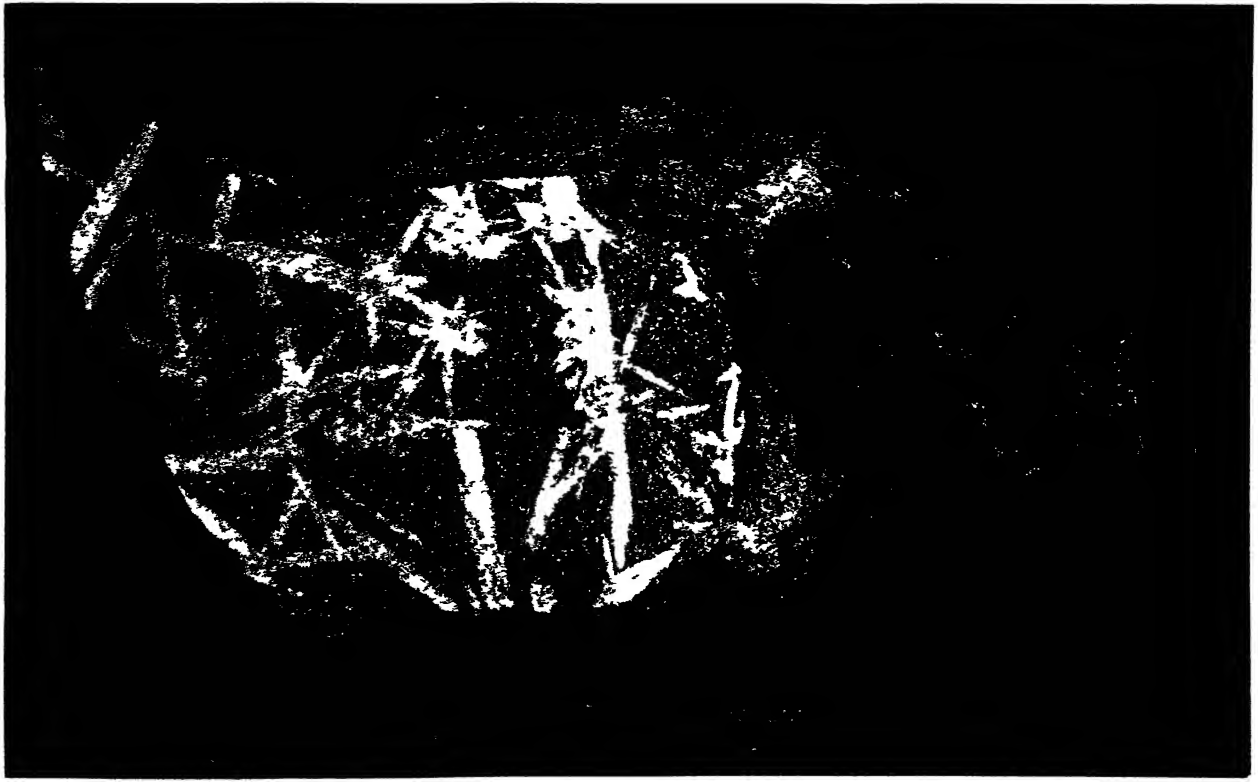
DURUNIS AND NATIVE WASHERS, ASSAM.

AURIFEROUS GRAVEL JANGLU PANI

FROM THE GORGE OF THE SUBANSIRI SHOWING THE GRAVEL BEACHES

J. M. Maclaren, Photo. *Lumière Co., Photo. Eng.*

AURIFEROUS BEACH, DERPAI POOL



BASIC ROCK WITH LARGE CRYSTALS OF SCAPOLITE